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A STUDY OF THE UTILITY OF PROTEIN PEPTIZATION BY INORGANIC SALT SOLUTIONS AS A MEANS OF PREDICTING LOAF VOLUME[1]

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In recent years many investigators have endeavoured to account for differences in flour strength from a colloidal viewpoint. Wood (1907), and Wood and Hardy (1908) were the first to point out that wheat flour proteins were typical emulsoid colloids and that the colloidal qualities of the proteins were of greater importance than their chemical properties in relation to flour strength.

Gortner and Doherty (1918), Sharp and Gortner (1922), and Gortner and Sharp (1923) have shown that wide differences exist in the imbibitional capacity of different glutens, the glutens from strong flours exhibiting a greater imbibitional capacity and a lesser degree of dispersion in aqueous solutions of acids and alkalis than glutens from weak flours.

This colloidal viewpoint has been strengthened by the extensive researches of Gortner, Hoffman and Sinclair (1928, 1929) on the peptizing action of certain salt solutions on a series of 12 samples, which represented flours milled from the various types of wheat grown extensively in the United States and Canada. They observed wide differences in the amount of protein that could be extracted from a given flour, their results showing that protein "solubility" was in reality peptization, since its extent was governed by the nature of the anions and cations present in the salt solution—a typical lyotropic series of anions and cations being obtained. It was shown that peptization was not hydrolysis as there was no increase in free amino or carboxyl groups, and, further, that the differences in extent of peptization with the various salts were not due to variations in H-ion concentration.

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Furthermore, with fixed concentrations of a given salt, wide differences were observed in the percentage of total protein extractable from different flours; the proteins of weak flours were more readily peptized than those of strong flours. These differences paralleled the behaviour of strong and weak glutens upon peptization with acid and alkali solutions, as had been previously observed, and indicated that the colloidal properties of the wheat flour proteins were involved. They suggested that these differences in colloidal behavior may be due to inherent differences in wheat varieties and also to environmental conditions under which the wheat was grown and harvested.

Gortner (1927) obtained high negative correlations between loaf volume and percentage of protein extractable by a given salt solution, reporting that of 13 coefficients computed, the lowest obtained was $r = -.672 \pm .017$ with normal KI solution, and the highest $-.925 \pm .028$ with normal $MgSO_4$ solution. This indicated that the larger the loaf volume, the smaller would be the percentage of the total protein peptized, and suggested that such determinations might be of value in the estimation of baking quality, and also in studies on frosted, rusted, sprouted, or otherwise damaged wheat.

Geddes (1930) in a study of the influence of heat on flour, found with increasing severity of heat treatment a marked and progressive decrease in viscosity, and in ease of peptization, of the flour proteins with normal $MgSO_4$ and normal KI solution which were paralleled by decreases in gas-retaining capacity of the doughs, and in loaf volume. High positive correlations were obtained between the percentages of protein extractable by each of the salts, which in turn were positively correlated with viscosity, indicating that the magnitude of these fractions was influenced by the colloidal properties of the flour proteins. High positive correlations resulted between loaf volume and percentage of protein peptized; this, however, would seem to have no bearing on the results obtained by Gortner and his co-workers, since they were working with native proteins, while in the case of the heated flours, more or less denatured proteins were being dealt with—which from a priori reasoning would result in decreased "solubility."

MacLeod (1929) using a simplified procedure determined the percentage of total protein peptized by 0.5N $MgSO_4$ and 0.5N KBr on a series of 29 flours utilized by Larmour and MacLeod (1929) in a study of the relative value of different baking methods in the

estimation of baking quality. Correlation coefficients calculated between the percentage of total protein peptized by these salts and the baking scores were found to be negative, the lowest being $-.284 \pm .12$ (between percentage peptized by 0.5N $MgSO_4$ and baking score basic formula) and the highest $-.788 \pm .05$ (between percentage protein peptized by 0.5N KBr and Arkady and malt formula).

Experimental

The investigations thus far reported on the applicability of the protein peptization test to the estimation of baking quality, although confined to rather limited series of flours, indicate that the method may be of great commercial value in the study of wheat quality. The present paper deals with the application of the method to flours experimentally milled from hard red spring wheats grown in Western Canada in 1928. A combination of conditions prevailed over the prairie provinces during the growing and harvesting seasons of 1928, which resulted in a wheat crop of low average quality. Owing to a period of limited rainfall following seeding, germination was not uniform; severe frosts occurred in the third week of August, resulting in many types of frost damage, combined with green and immature kernels throughout a large proportion of the crop.

For the purpose of making a preliminary survey of the baking quality of flours milled from immature and frosted wheat, 246 samples of the 1928 crop varying in grade from No. 1 Northern to "Feed" (Canadian grades) were collected by the Associate Committee on Grain Research, and distributed to the collaborating laboratories. This collection seemed an excellent source of raw material on which to determine chiefly whether flour proteins would exhibit differences in ease of peptization as a result of the presence of increasing quantities of green, immature and frosted kernels, and the extent to which these differences are related to loaf volume.

Of the 246 samples in the collection, 102, varying in grade from No. 2 Northern to No. 6, were utilized in the present study, 20 samples being selected at random for each grade (22 in the case of Grade No. 4). The wheat samples after cleaning and scouring were conditioned to 13% moisture 4 days prior to milling, a 2,000 g. sample was tempered to 15% moisture, and a straight grade flour milled on a two-stand Allis Chalmers experimental mill following the flow sheet published by Geddes (1929). The flours were aged in cotton sacks for thirty days prior to baking in a room main-

tained at approximately 70% humidity. The baking procedure used was a modification of the "Basic Standard Procedure" described by Blish (1928). The modifications have been detailed by Geddes (1929) and by Larmour (1929) and involve the use of 100 g. of flour (13.5% moisture basis), variable absorption, mechanical mixing, and baking in low-sided pans. (A constant absorption is not practical or desirable in such a series of flours, since the absorption may vary from 58% to 75%, the higher values being obtained in the case of flours milled from badly frosted wheats.) In all other respects the A. A. C. C. procedure was followed and the method thus modified is designated in this paper as the basic method. Loaf volume was determined in the measuring device described by Geddes and Binnington (1928). The duplicate bakings were made on consecutive days and bakes which failed to agree within 20 cc. were repeated. The samples were rebaked with the addition of 0.001% $KBrO_3$ to the baking formula (designated as the bromate method), and also with the addition of 1.0% Fleischmann's diastatic malt (designated as the malt method).

Total protein content of the flour was determined by the Kjeldahl-Gunning procedure and the results expressed on a 13.5% moisture basis. For determining the ease of peptization of the flour proteins 0.5N $MgSO_4$ solution was originally selected. Several considerations led us to utilize this salt. The data obtained by Gortner, Hoffman and Sinclair (1928, 1929) showed that variations in concentration of this salt had little influence on the percentage protein extracted. The highest correlation with loaf volume was obtained with normal $MgSO_4$ solution; the salt is cheap and readily obtainable in a fairly high state of purity. Previous experience with normal $MgSO_4$ solution revealed a very slow rate of digestion in the Kjeldahl determination and this led to our use of 0.5N $MgSO_4$ (Baker's C.P. grade). The method as outlined by Gortner and co-workers was followed. This consists essentially of three successive 30 minute extractions of 6 g. flour with 50 cc. salt solution and determination of the protein peptized by Kjeldahling the combined extracts. All determinations were made in duplicate and repeated when analytical agreement was not obtained. The results were calculated to a 13.5% moisture basis. As we had no knowledge of the influence of temperature on the extent of extraction it seemed of importance to conduct the extractions under as uniform temperature conditions as possible. The determinations were made in a room equipped with a thermostat and variations in temperature from day to day did not exceed 2°C.

The determination was found to be very laborious due to the difficulty experienced in putting the packed flour residue resulting from centrifugation, into suspension for the second and third extractions. In a personal communication Dr. R. K. Larmour, of the University of Saskatchewan, called our attention to the simplified procedure developed in his laboratory by MacLeod (1929). The method consisted in a single extraction of 6 g. flour with 200 cc. salt solution, by agitation in a mechanical shaker for two hours, centrifuging, and determining the protein on a 50 cc. aliquot of the supernatant liquid. This method was found to give somewhat higher results than the original Gortner procedure but the values were relative for different flours. Since our data for the amount of protein extracted by 0.5N $MgSO_4$ showed but slight variation between different samples, flours milled from wheats grading No. 2 and 3 Northern were extracted with 0.5N KBr, and flours from Grades 3 Northern, No. 4 and No. 6, with 0.5N KI, using the modified procedure in order to increase the spread in peptized protein between the different flours.

The results of these determinations, together with total protein content of the flour, loaf volumes and baking scores, by the basic, malt and bromate procedures are summarized according to wheat grade in Tables I to V inclusive (in the Appendix). For the sake of brevity the detailed baking data are omitted, but the computed baking score, calculated by the method detailed by Larmour (1929), summarizes the bread characteristics. The detailed data will be published by the Associate Committee on Grain Research, and in this paper loaf volume is the only characteristic considered, since in statistical studies it is desirable to use a figure which is subject to definite quantitative expression.

Experimental Results

The means and standard deviations for the analytical data are summarized according to wheat grade in Table I. The means for total protein, peptized protein and percentage total protein peptized are quite uniform for the different grades, no definite trend being evident, indicating that there is no essential difference between peptizability of the flour proteins from immature and frost damaged wheats, and sound wheats. It should be pointed out, however, that these commercial samples are of unknown history and are probably far from uniform in regard to variety and inherited characteristics. Such variations, however, are desirable in a study of the value of the peptization test in relation to wheat-grading

TABLE I

MEANS AND STANDARD DEVIATIONS

	Grade No.											
	2°		3°		4		5		6		Entire Series	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
% Total Protein (*a*)	11.88	0.827	10.98	1.462	11.28	1.306	11.31	1.271	11.21	0.957	11.33	1.227
% Peptized Protein												
0.5N $MgSO_4$ (b_1)	2.29	0.1114	2.24	0.1545	2.20	0.1516	2.31	0.1898	2.25	0.1496	2.26	0.1580
0.5N KBr (b_2)	4.11	0.2771	4.03	0.3204	....	.....	....	.....	...	.....	...	.....
0.5N KI (b_3)	....	.....	5.84	0.6283	5.92	0.6152	....	.....	5.59	0.4040	...	.....
% Total Protein Peptized												
0.5N $MgSO_4$ (d_1)	19.29	1.310	20.72	2.313	19.64	1.631	20.52	1.923	20.12	1.566	20.05	1.856
0.5N KBr (d_2)	34.69	2.177	37.09	3.118	....	.....	....	.....	...	.....	...	.....
0.5N KI (d_3)	....	.....	53.44	3.225	52.55	1.603	....	.....	49.96	2.378	...	.....
Loaf Volume in cc. (*e*)												
Basic method	547	35.26	537	35.50	556	48.03	564	63.39	529	57.99	547	50.89
Loaf Volume in cc. (*f*)												
Malt Method	618	44.12	593	44.38	606	53.96	581	78.45	562	70.39	592	62.86
Loaf Volume in cc. (*g*)												
Bromate method	610	55.99	569	72.33	567	77.31	551	94.92	494	71.38	558	84.12
Loaf Volume in cc. (*r*)												
Bromate—basic	+63	40.69	+32	64.3	+10	67.21	−13	55.47	−35	46.22	+12	65.42

problems. Peptization by the different salts is in relative agreement with the data of Gortner et al.

With regard to baking results, there is an increased variability in loaf volume as the wheat grade decreases, and in the case of the bromate data, a definite trend towards decreased loaf volume. The behaviour of these flours to the differential test is of particular interest, the response to bromate becoming progressively less as the grade of wheat decreases. The mean response to bromate is represented graphically in Fig. 1. Larmour and MacLeod (1929, 1929a) have adduced abundant evidence to emphasize the value of determining the bromate response of experimentally milled flours in estimating wheat quality—their behaviour in this respect giving reliable data for predicting the ability of a flour to stand up in a blend with weak flour. It is believed that the bromate baking method alone, gives a more reliable measure of quality than the basic procedure. Furthermore, Larmour (1930) also pointed out that the baking values obtained by this method on experimentally milled flours give much higher correlation coefficients with protein content of wheat and hence are more consistent with the commercial importance attached to the results of protein tests on wheat.

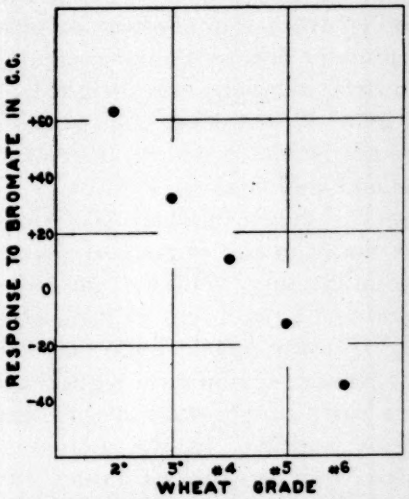

Fig. 1. Showing the mean response to bromate (loaf volume in cc. by bromate method—loaf volume in cc. by basic method) of flours milled from different wheat grades (Canadian grades, 1928 crop). Frost damage and immaturity were the principal factors operating to reduce the grade.

In view of these considerations, the bromate values for loaf volumes, taken in conjunction with the decreased response to bromate furnish very strong evidence that the mean baking quality of these flours decreases with grade. Their baking behaviour is not paralleled by any similar trend in peptizability of the flour proteins.

Total Correlation Coefficients

Our results have been submitted to a statistical study and the method of analysis developed has been applied to the published data of Gortner et al (1929), and also to the peptization results obtained by MacLeod (1929) on a portion of the series of flours on which the baking data has been published by Larmour and Mac-

Leod (1929.) These results are summarized in Table VI (Appendix). Of the 29 flours in the series of Larmour and MacLeod, 24 were 75% patent flours experimentally milled from wheats grown in plots in various parts of Saskatchewan in 1926 and 1927. These particular samples were all grown from the same lot of seed of a very pure strain of Marquis and were chosen from a large series similarly grown, because they exhibited the greatest range in protein content and apparent baking quality by the basic procedure. Of these flours of known history 3 were milled from wheats grading below No. 3 Northern. Excluding these 3, the series provided excellent material for a study of the value of the peptization test applied to flours milled from sound wheat of uni- from inherited characteristics grown under different environmental conditions. In our analysis of their data we therefore, included 21 samples (omitting Nos. 13, 21, and 24 to 30 inclusive, from consideration). Tables III and IV give the statistical constants calculated from the data of Larmour and MacLeod, and Gortner et al.

The total correlation coefficients (as shown in Table II) calculated from our own data bring out many of the important points regarding the relations between total protein, peptized and non-peptized protein, and the baking quality of the flours as measured by loaf volume. The significance of these coefficients may be judged by comparison with the 5% points or minimum significant values according to the number of pairs of observations. These values have been tabulated by Fisher (1928). In the individual grades the coefficients are calculated from 20 pairs of values and the 5% point is .444. Grade No. 4 is an exception in that 22 pairs of values were used and the corresponding 5% point for the correlation coefficient is .423. For the entire series of 102 pairs of values the 5% point is .195.

With regard to the actual calculation of the total coefficients, it may be of interest to point out the manner in which some of these were obtained in order to save additional labor. The total protein is designated by a, protein peptized with 0.5N $MgSO_4$, 0.5N KBr, and 0.5N KI by b_1, b_2, b_3, respectively, and the corresponding percentages of total protein peptized by d_1, d_2, and d_3, while loaf volume by the basic, malt, and bromate methods has been designated by e, f, and g.

The correlation coefficients r_{ae}, etc., are standard measures for the relation between total protein and loaf volume and are determined in any event. They were calculated directly as well as the coefficients, r_{be}, etc., for the relation between peptized protein and

TABLE II

Total Correlation Coefficients

Correlation Coefficient	Grade No. 2°	3°	4	5	6	Entire Series
r_{ab_1}	.449	.613	.746	.611	.506	.594
r_{ab_2}	.574	.823	...	...	...	...
r_{ab_3}	...	.919	.967	...	.818	...
r_{ad_1}	−.739	−.870	−.834	−.685	−.679	−.779
r_{ad_2}	−.518	−.856	...	...	...	...
r_{ad_3}	...	−.610	−.531	...	−.528	...
r_{ae}	.511	.533	.355	.717	.595	.511
r_{af}	.626	.796	.877	.688	.572	.679
r_{ag}	.575	.723	.864	.719	.654	.689
r_{ar}	.349	.519	.739	.441	.242	.491
r_{b_1e}	.698	.267	.448	.531	.472	.459
r_{b_2e}	.258	.410	...	...	...	...
r_{b_3e}	...	.405	.350	...	.703	...
r_{c_1e}	.440	.538	.331	.718	.561	.486
r_{c_2e}	.498	.534	...	...	...	...
r_{c_3e}	...	.572	.341	...	.428	...
r_{d_1e}	−.017	−.513	−.148	−.449	−.287	−.292
r_{d_2e}	−.291	−.506	...	...	...	...
r_{d_3e}	...	−.491	−.138	...	−.018	...
r_{b_1f}	.549	.497	.748	.517	.593	.521
r_{b_2f}	.553	.751	...	...	...	...
r_{b_3f}	...	.819	.886	...	.686	...
r_{c_1f}	.583	.792	.918	.667	.515	.658
r_{c_2f}	.517	.762	...	...	...	...
r_{c_3f}	...	.707	.824	...	.406	...
r_{d_1f}	−.258	−.698	−.664	−.406	−.144	−.438
r_{d_2f}	−.120	−.595	...	...	...	...
r_{d_3f}	...	−.330	−.323	...	.010	...
r_{b_1g}	.484	.546	.772	.464	.521	.503
r_{b_2g}	.432	.888	...	...	...	...
r_{b_3g}	...	.784	.889	...	.768	...
r_{c_1g}	.539	.708	.835	.709	.615	.671
r_{c_2g}	.505	.637	...	...	...	...
r_{c_3g}	...	.615	.797	...	.472	...
r_{d_1g}	−.240	−.590	−.603	−.475	−.308	−.458
r_{d_2g}	−.177	−.379	...	...	...	...
r_{d_3g}	...	−.228	−.272	...	−.017	...
$r_{b_1c_1}$	.332	.540	.688	.504	.376	.501
$r_{b_2c_2}$	.281	.728	...	...	...	...
$r_{b_3c_3}$	...	.779	.889	...	.568	...

NOTE—

a = % total protein in flour

b_1, b_2, b_3 = % peptized protein by 0.5N $MgSO_4$, 0.5N KBr & 0.5N KI respectively.

c_1, c_2, c_3 = % non peptized protein by 0.5N $MgSO_4$, 0.5N KBr & 0.5N KI respectively.

d_1, d_2, d_3 = % total protein peptized by 0.5N $MgSO_4$, 0.5N KBr & 0.5N KI respectively.

e, f, g = loaf volume by basic, malt and bromate methods respectively.

r = response to bromate in cc.

TABLE III

TOTAL CORRELATION COEFFICIENTS AND OTHER STATISTICS FROM DATA OF MACLEOD, AND OF LARMOUR AND MACLEOD ON FLOUR MILLED FROM SOUND MARQUIS WHEATS GROWN FROM SAME SEED

	Means	Standard Deviations	Total Correlations			
a	12.1	1.477	r_{ab_1}	.855	r_{c_2g}	.819
b_1	1.94	0.1675	r_{ab_2}	.941	r_{d_1e}	.074
b_2	4.11	0.4023	r_{ad_1}	−.777	r_{d_1f}	−.250
d_1	16.2	1.008	r_{ad_2}	−.722	r_{d_1g}	−.495
d_2	34.1	1.515	r_{ae}	.000	r_{d_2e}	−.120
e	259	27.04	r_{af}	.588	r_{d_2f}	−.334
f	302	34.91	r_{ag}	.847	r_{d_2g}	−.473
g	326	45.95	$r_{b_1c_1}$	.819		
			r_{b_1e}	.011		
			r_{b_1f}	.651		
			r_{b_1g}	.831		
			$r_{b_2c_2}$	.892		
			r_{b_2e}	−.063		
			r_{b_2f}	.597		
			r_{b_2g}	.843		
			r_{c_1e}	−.004		
			r_{c_1f}	.568		
			r_{c_1g}	.831		
			r_{c_2e}	.022		
			r_{c_2f}	.568		

TABLE IV

STATISTICAL ANALYSIS OF DATA PUBLISHED BY GORTNER, HOFFMAN, AND SINCLAIR (1929)

	Means	Standard Deviations	Total Correlation Coefficients	
a	12.18	1.485	r_{ab_1}	−.066
b_1	3.13	0.2539	r_{ab_2}	.612
b_2	4.69	0.6135	r_{ad_1}	−.830
d_1	26.18	4.401	r_{ad_2}	−.438
d_2	38.78	4.741	r_{ae}	.539
e	2057.5	116.1	$r_{b_1c_1}$	−.231
			$r_{b_2c_2}$	.243
			r_{b_1e}	−.399
			r_{b_2e}	−.222
			r_{c_1e}	.592
			r_{c_2e}	.773
			r_{d_1e}	−.673
			r_{d_2e}	−.845

loaf volume. Since $a = b + c$ where c is the non-peptized protein; $c = a - b$ and it can be shown easily that:

$$r_{ce} = r_{(a-b)e} = \frac{r_{ae}\sigma_a - r_{be}\sigma_b}{\sigma_{(a-b)}}$$

This provides a very simple method for obtaining the correlation coefficients between non-peptized protein and loaf volume, which are necessary in the calculation of partial or multiple correlations.

The correlations between total protein and per cent of total protein peptized were determined in order to obtain some measure of the constancy of b, the peptized protein. The manner in which these correlations r_{ad_1}, r_{ad_2}, and r_{ad_3}, measure this factor is obvious if we represent d as b/a, where a is the total protein. When b is a constant fraction of a the ratio b/a is a constant value and the correlation coefficient $r_{(b/a)a}$ becomes zero. On the other hand, if b is itself a constant value the coefficient $r_{(b/a)a}$ is negative and its magnitude is entirely due to the variation in total protein. It will not be equal to unity, however, even under these extreme circumstances as the relation between k/a and a where k is a constant value is obviously non-linear. The coefficient r_{ad} therefore does not approach – 1 as a limit as b approaches a constant value k.

The high negative values obtained for r_{ad} show that as the total protein increases the peptized protein does not increase relatively. This brings up the question as to whether or not this result is due to more incomplete extraction as the total protein increases. To satisfy ourselves on this point a series of the flours of varying protein content were extracted 6 times with 0.5N $MgSO_4$ by the Gortner procedure and the last 3 extracts combined and Kjeldahled, with the following results:

Sample No.	% Total Protein (13.5% Moisture Basis)	% Peptized Protein (13.5% Moisture Basis)
462	8.58	0.21
460	8.62	0.17
675	11.41	0.17
435	11.59	0.15
466	12.58	0.15
508	12.60	0.15
487	13.51	0.15
536	13.71	0.18

The high negative correlations for r_{ad} are, therefore, not to be attributed to incomplete extraction. Similar high negative values also have been obtained for the data of Gortner, and of MacLeod.

The next set of total correlation coefficients of considerable interest are those showing the relation between loaf volume and the percentage of the total protein peptized. This is the measure used by Gortner (1927) and for which high negative values were obtained. It seemed that this might be an important measure of the relative values of the peptized and non-peptized portions of the total protein, and it is therefore of interest to examine the nature of this correlation coefficient more closely. In our symbols the coefficient is represented by r_{de} which is equivalent to $r_{(b/a)e}$. In the first place it is obvious that part of the value $r_{(b/a)e}$ is due to r_{ae} and since the latter is likely to differ for different flours $r_{(b/a)e}$ cannot be used as an absolute measure of the relative values

of peptized and non-peptized protein. In the second place if the relation between a and e is a linear one the relation between (b/a) and e will tend to non-linearity and this must be true whether or not it can be demonstrated from the data. It is distinctly incorrect to measure non-linear relations by means of the correlation coefficient and therefore we must decide against its use for cases such as are being dealt with in this paper.

It follows also from this discussion that the percentage of the total protein peptized cannot be efficiently used as an indication of the baking quality of the flour as measured by the loaf volume. To date the best indicator of quality is the total protein and if the percentage of the total protein peptized is a better measure we would obtain higher values for $r_{(b/a)e}$ than r_{ae}. Table V summarizes the data on this point. It will be observed that for the frosted series the correlations r_{ae}, r_{af}, and r_{ag} are higher than the corresponding coefficients where (b/a) is involved. From the data of Larmour and MacLeod a comparison of their values is only possible for the malt and bromate methods of baking as the other group of coefficients is all quite insignificant. Here we note the same tendency as in the data from the frosted series. The one exception is provided by the data from Gortner, Hoffman, and Sinclair. These flours differ widely in quality and probably represent the extreme in this respect. It is obvious from an inspection of $r_{(b/a)e}$ that this value can only be greater than r_{ae} when b decreases as a increases. This was actually the case in the small series of flours studied by Gortner, Hoffman and Sinclair. The data from the other series, however, do not bear out the theory that this is a general phenomenon and indicate that on the whole, total protein is a distinctly better measure of quality than the per cent of the total protein peptized.

It is evident that r_{de}, r_{df}, r_{dg}, in part measure the constancy of the peptized protein. This is shown by the values of the coefficients when salts are used which peptize different proportions of the total protein. As will be noted from the footnotes in Table II, the symbol d_1 represents b_1/a where b_1 is the protein peptized by 0.5N $MgSO_4$, and d_2 represents b_2/a where b_2 is the protein peptized by 0.5N KBr. The latter takes out more protein than 0.5N $MgSO_4$ and therefore introduces a greater absolute variability in b. Again d_3 represents b_3/a where b_3 is the protein peptized by 0.5N KI and this salt takes out a still greater proportion of the total protein. Some of the correlation coefficients for the percentage of total protein peptized and loaf volume by the basic (e), malt (f) and the bromate (g) procedures are tabulated below:

	Grade 2	Grade 3	Grade 4	Grade 6
r_{d_1e}	...	−.513	−.148	−.287
r_{d_2e}	...	−.491	−.138	−.018
r_{d_1f}	...	−.698	−.664	−.144
r_{d_2f}	...	−.330	−.323	.010
r_{d_1g}	−.240	−.590	−.603	−.308
r_{d_2g}	−.177	−.379	...	...
r_{d_3g}	...	−.228	−.272	−.017

In every case we note that there is a reduction in the correlation coefficient with the salts peptizing more of the protein.

The total coefficients r_{ae}, r_{af}, r_{ag}, indicate that the malt and bromate methods give a somewhat closer relationship between loaf volume and protein content of the flour than the basic procedure.

TABLE V

COMPARISON OF CORRELATION COEFFICIENTS OBTAINED FROM TOTAL PROTEIN AND LOAF VOLUME WITH THOSE OBTAINED FROM PER CENT OF PROTEIN PEPTIZED AND LOAF VOLUME

	Frosted Wheat Series					
	Grade No.					
Correlation Coefficient	2°	3°	4	5	6	Entire Series
r_{ae}	.511	.533	.355	.717	.595	.511
r_{d_1e}	−.017	−.513	−.148	−.449	−.287	−.292
r_{d_2e}	−.291	−.506	...	...	...	...
r_{d_3e}	...	−.491	−.138	...	−.018	...
r_{af}	.626	.796	.877	.688	.572	.679
r_{d_1f}	−.258	−.698	−.664	−.406	−.144	−.438
r_{d_2f}	−.120	−.595	...	...	...	...
r_{d_3f}	...	−.330	−.323	...	−.010	...
r_{ag}	.575	.723	.864	.719	.654	.689
r_{d_1g}	−.240	−.590	−.603	−.475	−.308	−.458
r_{d_2g}	−.177	−.379	...	...	...	...
r_{d_3g}	...	−.228	−.272	...	−.017	...
Value at 5% point	.444	.444	.423	.444	.444	.195

Data From Larmour and MacLeod					
r_{ae}	.000	r_{af}	.588	r_{ag}	.847
r_{d_1e}	.074	r_{d_1f}	−.250	r_{d_1g}	−.495
r_{d_2e}	−.120	r_{d_2f}	−.334	r_{d_2g}	−.473
Value at 5% point	.433		.433		.433

Data from Gortner, Hoffman, and Sinclair	
r_{ae}	.539
r_{d_1e}	−.673
r_{d_2e}	−.845
Value at 5% point	.602

The correlations between protein content and response to bromate (r_{ar}), while not significant for grades 2 and 6, indicate that bromate response is in some measure related to protein content. By reference to Table I, it will be observed that the variability in protein is low in grades 2 and 6. It has already been noted that the mean protein content of the flours milled from the different grades is very similar, while the bromate response decreases algebraically with decreasing grade being negative for No. 5 and No. 6. The correlation r_{ar} nevertheless, is positive in all cases, indicating that the actual response of an experimentally milled flour to bromate depends in part on the quantity of protein present and in part on other factors usually included in the term, "protein quality."

Partial and Multiple Correlation Coefficients

As pointed out above, the simple correlation coefficient $r_{(b/a)e}$ is affected in part by changes in a (the total protein) and is therefore not a satisfactory measure of the relative value of the peptized and non-peptized portions in relation to baking quality. It remains to devise a method of analysis which will decide this point.

Any attempt at holding a constant by partial correlation methods brings out the fallacy of using such a variable as a in a study of this kind. Using the notation ${}_ar_{(b/a)e}$ to indicate that a is held constant it is obvious that ${}_ar_{(b/a)e}$ is approximately equal to ${}_ar_{be}$, thus eliminating the ratio b/a as a variable. ${}_ar_{(b/a)e}$ does not exactly equal ${}_ar_{be}$ because when a is small the variability of b/a is increased and when a is large it is decreased and this has some effect on the value of ${}_ar_{(b/a)e}$. If the non-peptized protein is represented by c we have $a = b + c$ and it would seem at first possible to compare the coefficients ${}_ar_{be}$ and ${}_ar_{ce}$ in order to measure the relative values of the two classes of protein. Actually, however, this reasoning is erroneous as $b = a - c$ giving:

$$ {}_ar_{be} = {}_ar_{(a-c)e} $$

In the coefficient ${}_ar_{(a-c)e}$, a is held constant so that we have beginning with ${}_ar_{be}$:

$$ {}_ar_{be} = {}_ar_{(a-c)e} = {}_ar_{-ce} = -{}_ar_{ce} $$

The two coefficients ${}_ar_{be}$ *and* ${}_ar_{ce}$ are, therefore, numerically equal and of opposite sign, and hence cannot be utilized to determine the relative values of the peptized and non-peptized portions because of the use of the variable a which contains both b and c.

In view of these considerations, one obvious method of analysis was to compare partial correlation coefficients such as ${}_{b_1}r_{c_1e}$, with ${}_{c_1}r_{b_1e}$, and ${}_{b_2}r_{c_2g}$. with ${}_{c_2}r_{b_2g}$. These coefficients are given in pairs in Table VI. If c, the non-peptized protein, is the more valuable, we would expect the value of ${}_br_{ce}$ to be higher than ${}_cr_{be}$, etc. With regard to

the frosted series, it will be noted from the figures for the entire series that this is in general true for 0.5N $MgSO_4$. For 0.5N KBr there seems to be no definite trend in either direction, while for 0.5N KI the situation is quite reversed, the peptized protein being the more valuable in

TABLE NO. VI

PARTIAL CORRELATION COEFFICIENTS

Correlation Coefficient	Grade No. 2°	3°	4	5	6	Entire Series	Average Coefficients
$b_1{}^r c_{1e}$	.309	.485	.035	.615	.469	.333	.383
$c_1{}^r b_{1e}$	.651	−.032	.321	.281	.340	.285	.312
$b_1{}^r c_{1f}$	.508	.717	.839	.550	.392	.537	.601
$c_1{}^r b_{1f}$	.463	.135	.406	.281	.503	.294	.358
$b_1{}^r c_{1g}$	.458	.586	.659	.621	.530	.561	.571
$c_1{}^r b_{1g}$	.383	.276	.495	.175	.396	.260	.345
$b_2{}^r c_{2e}$	.459	.378	...	...	...	...	.419
$c_2{}^r b_{2e}$	.142	.036	...	...	...	...	.089
$b_2{}^r c_{2f}$	.452	.475	...	...	...	...	.464
$c_2{}^r b_{2f}$	.496	.442	...	...	...	...	.469
$b_2{}^r c_{2g}$	.444	−.029	...	...	...	...	.207
$c_2{}^r b_{2g}$	.350	.802	...	...	...	...	.576
$b_3{}^r c_{3e}$	...	.447	.068	...	.049	...	.188
$c_3{}^r b_{3e}$	...	−.079	.109	...	.618	...	.216
$b_3{}^r c_{3f}$	...	.019	.169	...	.270	..	.153
$c_3{}^r b_{3f}$	...	.604	.595	...	.605	...	.601
$b_3{}^r c_{3g}$	...	.008	.032	...	.068	...	.036
$c_3{}^r b_{3g}$	...	.572	.652	...	.689	...	.638
Value at 5% point	.456	.456	.433	.456	.456	.195	

	Data from Larmour and MacLeod				
$b_1{}^r c_{1e}$	.560	$b_2{}^r c_{2e}$	.874		
$c_1{}^r b_{1e}$	−.333	$c_2{}^r b_{2e}$	−.666		
Value at 5% point	.444		.444		
	Data from Gortner, Hoffman and Sinclair				
$b_1{}^r c_{1e}$	.009	$b_1{}^r c_{1f}$	.080	$b_1{}^r c_{1g}$	.464
$c_1{}^r b_{1e}$	−.014	$c_1{}^r b_{1f}$	.393	$c_1{}^r b_{1g}$	.467
$b_2{}^r c_{2e}$	.174	$b_2{}^r c_{2f}$	.097	$b_2{}^r c_{2g}$	.317
$c_2{}^r b_{2e}$	.183	$c_2{}^r b_{2f}$	.243	$c_2{}^r b_{2g}$	.459
Value at 5% point	.603		.603		.603

relation to baking quality. This point will be referred to later, in connection with Kent-Jones' (1927) theory of optimum coagulation.

In the Larmour and MacLeod data there is no definite trend in either direction (especially since the partial coefficients are nearly all insignificant), while the data from Gortner, Hoffman, and Sinclair show a decided trend in favour of the non-peptized protein.

The second method of analysis was designed to determine the practical significance, for purposes of predicting flour quality, of knowing the amounts of peptized and non-peptized protein in addition to the total protein. When only one independent variable is concerned such as a the total amount of information which it gives is expressed by the correlation coefficient r_{ae} where e is the dependent variable. When two independent variables such as b and c are concerned the total amount of information in regard to the dependent variable e is expressed by the multiple correlation coefficient $R_{(bc)e}$. If it is worth while splitting up the protein into two fractions and measuring the amount of each fraction the coefficient $R_{(bc)e}$ will enable us to make a closer estimate of e than r_{ae}. We cannot compare the two coefficients directly because they have been calculated from the same data and will probably be in themselves correlated. An analysis of variance, however, can be applied which enables one to judge whether or not the additional knowledge with regard to the amount of peptized protein is of value. This test was suggested to the authors by Dr. R. A. Fisher and is based on his method of applying the analysis of variance to determining the significance of regression coefficients.

In dealing with two variables such as a and e in which e is considered the dependent and a the independent variable the significance of the regression of e on a is determined by the following method of analysis:

Variance due to	*Sum of squares*	*Degrees of freedom*	*Mean squares*
Regression function....	$b^2S(a-\bar{a})^2$	1	$\frac{b^2S(a-\bar{a})^2}{1}$
Deviations from regression function....	$S(e-E)^2$	n^1-2	$\frac{S(e-E)^2}{n^1-2}$
Total	$S(e-\bar{e})^2$	n^1-1	

Where E is the regression function $E=\bar{e}+b\ (a-\bar{a})$. The mean squares contributed by the regression function and by the deviations from the regression function are then compared by the usual method, (Fisher, 1928) of finding the value of z and referring to a table giving z values at the 5% and 1% points for different degrees of freedom.

The significance of a multiple regression is tested in the same manner again comparing the variance due to the regression function with that due to deviations from regression. It must be remembered however, that the regression function is represented by as many degrees of freedom as there are independent variables.

Considering the regression of e on a when 20 pairs of values are used we have the sum of squares $S(e—E)^2$ contributed by 18 degrees of freedom. In the regression of b and c on e we have the sum of squares $S(e—E^1)^2$ contributed by 17 degrees of freedom. It is therefore possible to set up another analysis as follows:

Variance due to	*Sum of Squares*	*Degrees of Freedom*	*Mean Square*
(1) Deviations from regression of a on e	$S(e-E)^2$	18	$\frac{S(e-E)^2}{18}$
(2) Deviations from regression of b and c on e	$S(e-E^1)^2$	17	$\frac{S(e-E^1)^2}{17}$
(3) Additional degree of freedom	$S(e-E)^2-S(e-E^1)^2$	1	$\frac{S(e-E)^2-S(e-E^1)^2}{1}$

in which the estimates of variance due to (2) and (3) may be compared by the z test. In general the deviations from the regression are less and consequently the sum of squares of these deviations are less as more independent variables are introduced. However the greater accuracy with which the regression line fits the actual points may not be commensurate with the loss of an additional degree of freedom with each new variable that is considered and we may actually lose in accuracy of estimation by introducing more variables. This test therefore is particularly applicable to the case in hand. It is a matter of routine procedure in wheat and flour analysis to determine the total protein, from which an estimate may be made of the quality. In making an additional determination such as the quantity of the total protein peptized we lose one degree of freedom and we wish to know whether the new information has increased or decreased the accuracy of our estimate.

This test was carried out on all of the pairs of correlation coefficients such as r_{ae} and $R_{(b_1c_1)e}$ and the results are given in Table VII. Where the z value indicates a gain in accuracy it is followed by a plus sign and where the z value indicates a loss of accuracy it is followed by a minus sign.

Considering the entire series of frosted samples it appears from the z values that the utility of determining the amount of protein peptized is greater for the basic method than for the malt or bromate methods of baking. This is probably related to the closer association between total protein and loaf volume when the improvers are used. As the total coefficient r_{ae} increases, the multiple $R_{(bc)e}$ does not increase accordingly.

For the individual grades we notice no definite trend in favour of the multiple correlation.

It will assist in analyzing this table on the basis of the z values calculated to remember that a significant increase in the multiple over the total coefficient is indicated by a z value of about .7466 for the grade samples of 20 pairs of values and in other samples according to the number of degrees of freedom. In cases, however, in which a loss of information is indicated (those cases in which a minus sign is placed after the z value) the table of z must be entered in the other direction and the 5% point is at about 2.75. There are therefore in Table VII, no indications of a significant loss of information when the protein fractions instead of the total protein are used for purposes of estimation.

In the Larmour and MacLeod series there is no evidence of a gain from the peptization test.

The Gortner et al series gives a significant value of z for the 0.5N KBr peptization test but for 0.5N $MgSO_4$ the results are quite insignificant.

Discussion

It appears somewhat difficult to correlate and interpret the data thus far published on peptization. The extensive researches of Gortner and his co-workers furnish strong evidence that the colloidal condition of the flour proteins is involved. This is confirmed by the peptization results Geddes (1930) obtained on one flour subjected to various heat treatments and which showed that peptizability progressively decreased with increasing heat denaturation or coagulation. In this series of heated treated flours the loaf volume at first increased slightly with decreasing peptization and then decreased, the decreases in loaf volume (especially when determined by the bromate method) and peptizability closely parallelling each other. These results, taken in conjunction with the change in the relative value of the peptized and non-peptized protein fractions of the frosted series reported in this paper, when determined by 0.5N $MgSO_4$, 0.5N KBr, and 0.5N KI support the suggestion of Kent-Jones (1927) that, for satisfactory baking quality, the colloidal state of the proteins must be within certain limits. He states:

> "It would appear that some weak flours, such as English, are too dispersed (too much in the sol state), while others, such as Indians, are too coagulated. Strength, then, depends on the proteins being within certain limits of dispersion, and beyond these limits, in either direction, poor baking quality will result."

TABLE NO. VII

Comparison by Analysis of Variance of Total and Multiple Correlation Coefficients

Frosted Series

Correlation Coefficient	Grade No. 2°	3°	4	5	6	Entire Series
r_{ae}	.511	.533	.355	.717	.595	.511
$R_{(b_1c_1)e}$	.732	.538	.449	.744	.627	.546
z	1.1543+	1.0326−	.2939+	.2021+	.0455+	.8255+
r_{ae}	.511	.533				
$R_{(b_2c_2)e}$	.513	.535				
z	1.5132−	1.4979−				
r_{ae}		.533			.595	
$R_{(b_3c_3)e}$		.575			.704	
z		.0828+			.7810+	
r_{af}	.626	.796	.877	.688	.572	.679
$R_{(b_1c_1)f}$	.694	.796	.932	.699	.672	.694
z	.5394+	.3850−	1.3344+	.3417−	.6757+	.6884+
r_{af}	.626	.796				
$R_{(b_2c_2)f}$	.669	.814				
z	.2694+	.1908+				
r_{af}		.796	.877		.572	
$R_{(b_3c_3)f}$		.819	.890		.713	
z		.3255+	.3734+		.9180+	
r_{ag}	.575	.723	.864	.719	.654	.689
$R_{(b_1c_1)g}$	.628	.735	.878	.720	.690	.698
z	.2918+	.2169−	.3548+	1.4472−	.2259+	.4386+
r_{ag}		.723				
$R_{(b_2c_2)g}$		.889				
z	...	1.5400+				
r_{ag}	...	.723	.864		.654	
$R_{(b_3c_3)g}$	...	.784	.889		.769	
z		.6997+	.6908+		.9600+	
Value of z at 5% point	+.7466	+.7466	+.7386	+.7466	+.7466	+.6729

Data from Larmour and MacLeod

r_{ae}	.000	r_{af}	.588	r_{ag}	.847
$R_{(b_1c_1)e}$	.014	$R_{(b_1c_1)f}$	.654	$R_{(b_1c_1)g}$	.871
z	2.8130—	z	.4731+	z	.4698+
r_{ae}	.000	r_{af}	.588	r_{ag}	.847
$R_{(b_2c_2)e}$	.185	$R_{(b_2c_2)f}$	.602	$R_{(b_2c_2)g}$	.860
z	.2247—	z	.3787—	z	.1219+
Value of z at 5% point	+.7424		+.7424		+.7568

Data from Gertner, Hoffman and Sinclair

r_{ae}	.539	r_{ae}	.539
$R_{(b_1c_1)e}$	.651	$R_{(b_2c_2)e}$	.881
z	.3668+	z	1.4855+
Value of z at 5% point	+.8163		+.8163

It seems logical to assume that the first protein fractions removed consist of the more highly dispersed (less highly coagulated) protein which is inferior in relation to baking quality. As more and more of the total protein is added to the peptized fraction by the use of salts of greater peptizing power, the fraction not peptized consists of protein in a progressively less dispersed or more coagulated condition. The addition of protein increments of increasing degree of coagulation to the peptized fraction would improve the general quality of the entire fraction. At some point a maximum difference between the baking value of the two proteins in favor of the non-peptized fraction would be obtained and at another point the two fractions would be of equal value. On the basis of the optimum coagulation theory, the further transfer of coagulated protein to the peptized fraction leaving a too highly coagulated protein in the non-peptized portion, would show an increasing inferiority for this portion, by the use of salts with greater and greater peptizing power.

If these premises are valid, they explain the partial correlations calculated from the peptization results by 0.5N $MgSO_4$, 0.5N KBr, and 0.5N KI. They also provide an interpretation of the differences in value between peptized and non-peptized protein as determined by 0.5N $MgSO_4$, and 0.5N KBr on the three sets of data studied in this paper.

The MacLeod data show no difference in value between peptized and non-peptized protein, the data from the frozen wheat series show more significant differences—the non-peptized being of greater value in general. In the data of Gortner et al the results are much more conclusive and appear to show clearly the relatively greater value of non-peptized protein. That such a series should exist is extremely interesting and it seems worth while to inquire into the possibility of any fundamental differences between the sets of flours used. As indicated above, the MacLeod flours were obtained from wheats grown from the same seed, but under varying environmental conditions. The frozen wheat flours were commercial grades in which the damage was almost entirely due to frost and to immaturity. The Gortner flours were commercial flours of widely different types and origins.

On the one hand we have flours milled from sound hard red spring wheat from the same seed which were, therefore, genetically similar. It is probable that the flour proteins lie very close to the optimum colloidal condition so that there is little difference in the relative value of the peptized and non-peptized fractions using

0.5N $MgSO_4$ and 0.5N KBr. On the other hand, Gortner and his associates worked with flours differing widely in type and origin, some of which were weak. In this series the proteins of some of the flours studied were probably too highly dispersed and the non-peptized protein of this series is the more valuable. In the frozen wheat series a greater variation in the state of coagulation of the proteins would probably exist than in the MacLeod series, but varying less widely in this respect than in the Gortner series, due to wider genetic differences in the latter.

The results on the frozen wheat series indicate that the test would be of no practical value in detecting flours milled from immature and frost damaged wheat, nor do the results on the carefully selected series of MacLeod offer much encouragement as to its utility in studies of the influence of environment on wheat quality. The method would, therefore, appear to be of little value in estimating such variations in baking quality as occur between flours milled from the same type of wheat.

From the data at present available, a determination of the peptized and non-peptized protein appears to be of little practical significance in predicting the baking quality of a flour, since, in general, practically as much information is yielded by a knowledge of the total protein.

Summary

Peptization studies have been conducted on 102 straight grade flours, experimentally milled from commercial samples of hard red spring wheat grown in Western Canada in 1928. These samples included wheats grading from No. 2 Northern to No. 6, the predominating forms of damage in the lower grades being immature and frosted kernels. Peptization determinations were conducted on the entire series with 0.5N $MgSO_4$, using the Gortner method. and on a part of the series with 0.5N KBr and 0.5N KI by a simplified procedure. The samples were baked by the basic, malt and bromate formulas.

The mean total protein and peptized protein were quite uniform for the different grades indicating no essential difference between peptizability of the flour proteins from sound wheat, and immature and frost damaged wheat. Baking results with the bromate formula, combined with progressively decreasing responses to the differential test indicated inferior baking quality with decreasing grade.

High negative correlations were obtained between total protein and percentage total protein peptized, which were not due to less complete extraction of the high protein flours.

The response of an experimentally milled flour to bromate depends, in part, on the quantity of protein present and in part on other facts usually included in the term "protein quality."

Correlations computed between percentage of the total protein peptized and loaf volume are not a satisfactory measure of the relative value of the peptized and non-peptized fractions for baking purposes, since their magnitude is, in part, a reflection of the relation between total protein and loaf volume.

Partial correlations involving the use of total protein as an invariate with peptized and non-peptized protein as variables cannot be utilized because total protein contains both these fractions.

A satisfactory comparison of the two protein fractions may be made by computing partial correlations using peptized protein, non-peptized protein and loaf volume.

The basic baking procedure revealed no significant difference in the relative value of the peptized and non-peptized protein fractions for baking purposes and also gave somewhat lower correlations between protein content of flour and loaf volume than the malt and bromate methods.

The peptization data with 0.5N $MgSO_4$ showed the non-peptized protein to be somewhat superior to peptized protein in its effect on loaf volume, while the results with 0.5N KI revealed the peptized protein to be superior. The data for 0.5N KBr were not significant.

An analysis of the peptization data (with 0.5N $MgSO_4$ and 0.5N KI) obtained by Gortner on flours milled from wheat differing widely in type and origin reveals greater differences (in favor of the non-peptized protein) than obtained in our studies, while the data of MacLeod on Marquis wheat grown from the same seed under different environmental conditions revealed no significant difference between the baking value of the two fractions.

The "optimum coagulation" theory affords an explanation of the peptization data thus far published.

A method for estimating the practical significance, for purposes of predicting loaf volume, of determining peptized and non-peptized protein in addition to total protein has been devised. Application of this method to the peptization data thus far published indicates that little additional information as to the probable baking value of the flour is obtained than when total protein alone is known.

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(Bibliography concluded on p. 556)

Appendix

TABLE NO. I

ANALYTICAL DATA ON STRAIGHT GRADE FLOURS MILLED FROM WHEATS GRADING 2 NORTHERN

Lab. No.	Total Protein (13.5% Moisture Basis)	Peptized Protein (13.5% Moisture Basis)		Total Protein Peptized		Loaf Volume			Computed Baking Score		
		0.5N $MgSO_4$	0.5N KBr	0.5N $MgSO_4$	0.5N KBr	Basic Method	Malt Method	Bromate Method	Basic Method	Malt Method	Bromate Method
	%	%	%	%	%	cc.	cc.	cc.			
429	10.81	2.36	4.09	21.8	37.8	561	607	584	79	79	81
446	11.12	2.14	3.85	19.2	34.6	536	616	571	69	75	77
449	12.65	2.38	4.46	18.7	35.2	551	647	546	75	97	71
450	11.27	2.40	3.94	21.2	35.0	535	588	542	67	71	70
466	12.58	2.29	4.18	18.2	33.2	550	624	637	75	89	89
467	12.00	2.23	4.01	18.6	33.4	567	644	615	78	89	83
472	11.14	2.21	3.92	19.9	35.2	473	534	541	44	56	68
475	10.58	2.24	4.02	21.1	38.0	528	605	608	68	78	84
508	12.60	2.46	4.13	19.5	32.8	572	602	668	73	73	102
547	12.78	2.33	4.18	18.2	32.7	585	645	666	78	87	96
552	13.13	2.51	4.32	19.2	32.9	607	707	737	80	101	121
619	11.99	2.44	3.99	20.5	33.3	630	709	706	85	103	104
640	12.24	2.11	3.88	17.1	31.7	504	581	630	56	73	90
646	10.15	2.21	3.74	21.7	36.8	510	536	559	56	65	71
653	11.25	2.12	3.87	18.9	34.4	522	592	571	62	78	76
654	11.38	2.17	4.18	19.0	36.7	523	606	580	61	76	83
665	12.65	2.29	4.31	18.0	34.1	527	613	609	69	85	87
666	12.35	2.34	4.36	19.0	35.3	534	627	609	65	79	89
702	12.41	2.26	3.85	18.2	31.0	569	607	546	70	75	68
719	12.58	2.25	4.99	17.8	39.7	558	671	680	70	92	96

TABLE NO. II

ANALYTICAL DATA ON STRAIGHT GRADE FLOURS MILLED FROM WHEATS GRADING NO. 3 NORTHERN

Lab. No.	Total Protein (13.5% Moisture Basis)	Peptized Protein (13.5% Moisture Basis)			Total Protein Peptized			Loaf Volume			Computed Baking Score		
		0.5N $MgSO_4$	0.5N KBr	0.5N KI	0.5N $MgSO_4$	0.5N KBr	0.5N KI	Basic Method	Malt Method	Bromate Method	Basic Method	Malt Method	Bromate Method
	%	%	%	%	%	%	%	cc.	cc.	cc.			
430	11.42	2.40	4.00	5.54	21.0	35.0	48.5	559	572	546	76	71	67
460	8.62	1.90	3.36	4.55	22.1	39.0	52.8	516	561	489	65	73	54
464	8.40	2.06	3.45	4.68	24.5	41.1	55.7	465	487	387	40	43	24
468	11.04	2.14	4.06	5.78	19.4	36.8	52.4	516	652	562	56	87	69
479	11.24	2.27	4.03	5.81	20.3	35.8	51.7	580	598	560	78	81	70
487	13.51	2.33	4.16	6.83	17.2	30.8	50.6	576	650	590	73	96	81
490	12.83	2.39	4.52	6.53	18.7	35.2	50.9	573	634	642	74	90	94
496	11.76	2.37	4.10	6.04	20.2	34.9	51.4	559	591	567	76	81	71
500	8.71	2.10	3.47	4.93	24.1	39.8	56.6	551	511	426	59	50	28
538	11.68	2.23	4.28	6.06	19.0	36.6	51.9	577	592	651	74	76	93
639	12.29	2.29	4.48	6.27	18.6	36.4	51.0	537	603	658	67	79	102
647	9.06	2.21	4.08	5.88	24.3	45.0	64.9	488	577	572	52	71	76
658	12.33	2.14	4.19	6.44	17.3	34.0	52.2	508	630	576	64	80	75
661	11.82	2.38	4.54	6.45	20.2	38.4	54.6	551	637	693	58	75	98
675	11.41	2.32	4.21	6.15	20.3	36.9	53.9	588	646	612	85	91	83
680	10.57	2.52	3.99	5.74	24.0	37.7	54.3	463	576	561	48	64	58
700	11.14	2.14	3.93	6.02	19.3	35.3	54.0	535	587	622	66	76	84
707	12.36	2.44	4.10	6.56	19.7	33.2	53.1	537	633	586	69	88	79
709	10.19	2.00	3.93	5.47	19.8	38.6	53.7	524	539	513	64	54	56
724	9.15	2.22	3.75	5.00	24.4	41.0	54.6	542	578	573	63	72	76

TABLE NO. III

ANALYTICAL DATA ON STRAIGHT GRADE FLOURS MILLED FROM WHEATS GRADING NO. 4

Lab. No.	Total Protein (13.5% Moisture Basis)	Peptized Protein (13.5% Moisture Basis)		Total Protein Peptized		Loaf Volume			Computed Baking Score		
		0.5N $MgSO_4$	0.5N KI	0.5N $MgSO_4$	0.5N KI	Basic Method	Malt Method	Bromate Method	Basic Method	Malt Method	Bromate Method
	%	%	%	%	%	cc.	cc.	cc.			
426	12.01	2.37	6.21	19.7	51.7	605	650	602	84	94	82
427	12.52	2.23	5.98	17.8	47.8	606	655	581	76	95	81
428	10.55	2.17	5.54	20.5	52.5	641	601	572	93	77	75
434	11.97	2.04	6.18	17.0	51.6	514	627	585	61	83	76
435	11.59	2.05	6.08	17.7	52.4	530	616	581	68	83	87
444	12.52	2.34	6.50	18.7	51.9	575	660	577	84	103	88
447	11.20	2.39	5.88	21.3	52.5	554	645	596	77	98	88
451	10.50	2.20	5.77	20.9	55.0	503	574	460	66	64	38
457	11.59	2.08	6.17	17.9	53.2	583	645	564	87	96	62
458	13.01	2.30	6.64	17.7	51.0	611	640	656	82	89	99
459	9.05	2.05	5.02	22.8	55.5	526	533	518	63	66	58
462	8.58	1.88	4.53	21.9	52.8	434	457	371	25	30	21
497	9.40	2.04	5.02	21.7	53.4	593	528	495	73	55	54
536	13.71	2.58	7.16	18.8	52.2	587	674	721	75	93	110
625	12.22	2.32	6.58	19.0	53.8	550	625	680	63	78	96
628	12.14	2.27	6.36	18.8	52.4	569	653	667	69	86	98
650	12.26	2.31	6.31	18.8	51.5	503	616	611	54	83	85
651	11.24	2.16	6.05	19.3	53.8	562	611	552	74	81	70
668	10.06	2.11	5.17	20.9	51.4	506	525	476	56	55	44
671	10.45	2.10	5.43	20.0	52.0	531	550	499	67	61	54
672	11.92	2.23	6.25	18.7	52.4	537	623	574	67	86	80
679	9.78	2.19	5.41	22.3	55.3	624	616	527	84	81	61

TABLE NO. IV

ANALYTICAL DATA ON STRAIGHT GRADE FLOURS MILLED FROM WHEATS GRADING NO. 5

Lab. No.	Total Protein (13.5% Moisture Basis)	Peptized Protein (13.5% Moisture Basis) 0.5N $MgSO_4$	Total Protein Peptized 0.5N $MgSO_4$	Loaf Volume			Computed Baking Score		
				Basic Method	Malt Method	Bromate Method	Basic Method	Malt Method	Bromate Method
	%	%	%	cc.	cc.	cc.			
414	13.22	2.49	18.7	720	737	730	119	110	109
437	11.16	2.38	21.2	551	538	572	67	62	75
448	11.28	2.33	20.6	560	620	529	73	85	68
452	11.78	2.54	21.5	591	672	542	93	92	69
453	10.86	2.33	21.4	606	625	505	95	88	57
465	10.81	2.15	19.9	597	432	550	83	43	57
469	9.96	2.17	21.8	592	631	621	86	86	84
470	10.61	2.20	20.7	550	596	506	64	75	46
476	11.18	2.46	22.0	577	595	625	75	75	89
493	13.23	2.69	20.1	627	625	584	87	84	76
493	8.93	2.33	26.1	401	414	355	26	25	15
504	13.04	2.60	20.0	611	612	746	81	73	111
537	13.87	2.36	17.0	617	669	707	94	92	108
622	11.18	2.43	21.7	554	585	486	60	68	45
660	9.74	2.21	22.8	540	535	492	57	59	41
704	10.82	2.07	19.2	530	562	513	64	64	58
720	12.23	2.20	18.0	550	629	537	73	82	65
721	11.86	2.22	18.8	530	552	478	63	61	50
729	9.68	1.90	19.6	491	496	513	52	49	55
731	10.84	2.09	19.2	480	488	430	48	50	35

TABLE NO. V

ANALYTICAL DATA ON STRAIGHT GRADE FLOURS MILLED FROM WHEATS GRADING NO. 6

Lab. No.	Total Protein (13.5% Moisture Basis)	Peptized Protein (13.5% Moisture Basis)		Total Protein Peptized		Loaf Volume			Computed Baking Score		
		0.5N $MgSO_4$	0.5N KI	0.5N $MgSO_4$	0.5N KI	Basic Method	Malt Method	Bromate Method	Basic Method	Malt Method	Bromate Method
	%	%	%	%	%	cc.	cc.	cc.			
421	12.40	2.31	5.99	18.6	48.3	552	543	434	68	61	37
425	13.47	2.53	6.22	18.7	46.2	543	633	583	69	84	81
436	11.66	2.18	5.88	18.6	50.4	584	616	547	82	75	68
445	11.44	2.34	5.57	20.5	48.7	577	613	504	90	98	55
454	10.92	2.14	5.20	19.6	47.6	528	542	439	57	62	34
456	10.99	2.21	5.66	20.1	51.5	567	645	618	75	97	89
461	10.19	2.21	5.33	21.7	52.3	551	578	471	73	71	42
471	11.01	2.32	5.60	21.1	50.9	552	570	517	65	67	53
509	10.34	2.34	5.62	22.6	54.4	533	572	441	70	71	33
541	11.76	2.44	6.17	20.7	52.5	555	631	599	64	81	82
623	10.96	2.44	5.55	22.4	50.6	567	682	526	62	86	54
631	12.19	2.32	6.05	19.0	49.6	540	570	561	61	66	71
636	11.00	2.41	5.75	21.9	52.3	508	507	447	47	50	33
648	11.33	2.14	5.37	18.9	47.4	492	506	470	48	48	38
652	10.96	2.11	5.38	19.3	48.2	517	522	481	60	56	41
657	11.92	2.36	6.17	19.7	51.8	596	590	572	76	69	70
663	10.34	2.02	5.16	19.6	49.9	536	518	457	61	48	35
667	10.16	2.05	5.21	20.3	51.3	431	483	413	36	44	33
713	9.02	2.07	4.60	22.7	51.0	328	351	316	11	14	4
726	12.20	2.02	5.41	16.5	44.3	531	565	490	60	63	53

TABLE NO. VI

TOTAL PROTEIN, PEPTIZED PROTEIN AND BAKING DATA COMPILED FROM THE ANALYTICAL RESULTS OF LARMOUR AND MACLEOD

No.	Nature of Sample	Grade	Total Protein in Flour (13.5% Moisture Basis)	Peptized Protein (13.5% Moisture Basis)		Total Protein Peptized		Loaf Volume			Computed Baking Score		
				0.5N $MgSO_4$	0.5N KBr	0.5N $MgSO_4$	0.5N KBr	Basic Method	Brom. Method	M&A Method	Basic	Brom.	Malt & Ark
			%	%	%	%	%	cc.	cc.	cc.			
1	Marquis 10B 1926	2°	14.5	2.1	4.8	14.8	32.9	225	325	...	59	105	...
2	Marquis 10B 1926	1°	11.2	1.9	4.0	17.0	35.9	248	298	320	71	98	103
3	Marquis 10B 1926	1° hard	12.0	1.9	4.2	15.9	34.7	230	282	303	66	93	101
4	Marquis 10B 1926	1°	13.8	2.2	4.7	15.7	33.9	233	305	358	63	101	124
5	Marquis 10B 1926	1°	12.7	2.1	4.4	16.2	34.9	225	290	350	56	89	116
6	Marquis 10B 1926	2°	13.5	2.0	4.4	15.2	32.7	320	333	...	108	110	...
7	Marquis 10B 1926	1°	10.7	1.9	3.7	17.7	35.0	250	275	305	68	88	100
8	Marquis 10B 1926	1°	13.1	2.0	4.0	15.1	30.7	215	265	333	53	84	114
9	Marquis 10B 1926	1°	11.9	1.9	4.1	16.3	34.1	255	315	...	78	103	...
10	Marquis 10B 1926	3°	13.4	2.3	4.5	17.2	33.7	290	418	438	81	144	152
11	Marquis 10B 1926	2°	15.6	2.3	5.0	14.7	31.8	290	344	405	90	114	138
12	Marquis 10B 1927	2°	9.8	1.8	3.5	18.2	36.1	263	270	263	84	86	79
13	Marquis 10B 1927	No. 5	12.4	2.1	4.2	17.2	33.9	308	322	343	98	105	114
14	Marquis 10B 1927	3°	10.0	1.7	3.6	17.4	36.4	268	278	260	82	89	76
15	Marquis 10B 1927	3°	11.5	1.8	3.9	16.0	34.2	249	282	330	75	89	113
16	Marquis 10B 1927	3°	13.1	1.9	4.4	14.8	33.7	263	305	368	78	97	124
17	Marquis 10B 1927	1°	11.7	1.8	4.0	15.7	34.2	267	295	300	84	96	100
18	Marquis 10B 1927	3°	10.9	1.8	4.0	16.3	36.5	233	275	328	64	84	111
19	Marquis 10B 1927	2°	11.7	1.9	3.7	16.0	31.9	283	288	300	91	91	101
20	Marquis 10B 1927	2°	11.9	1.8	3.9	15.2	33.1	275	338	343	85	115	118
21	Marquis 10B 1927	No. 4	11.0	2.0	4.0	18.5	36.1	305	305	315	100	99	102
22	Marquis 10B 1927	2°	10.6	1.8	3.7	17.4	34.9	263	260	265	81	81	85
23	Marquis 10B 1927	3°	10.7	1.8	3.8	16.9	35.1	303	300	293	99	98	93
24	First Pat. Flour Unblchd		10.0	2.0	3.7	19.7	37.1	315	322	308	113	113	104
25	First Pat. Flour Bleached		10.5	1.8	3.6	17.5	34.4	303	310	290	121	122	110
26	Marquis Ottawa 15, '27	3°	12.6	2.1	4.2	16.9	33.1	278	255	282	91	84	98
27	Pacific White Club		5.6	1.2	2.4	21.4	42.0	175	173	215	−11	−7	15
28	Marquis 10B, 1927	No. 4	10.2	2.0	3.8	20.1	37.4	297	270	288	90	80	85
30	Garnet, 1927	No. 5	7.4	1.6	2.9	22.1	38.9	210	192	200	32	29	30

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SHELF TO INCREASE ASHING CAPACITY OF LABORATORY ELECTRIC FURNACE

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The floor area of the laboratory electric furnace limits the number of ash determinations that can be run with each charge. This floor area can be approximately doubled by a simple removable shelf easily constructed in any laboratory. The subsequent plan of construction of shelf and supports gives a maximum working area and convenience of location of parts, and requires no alterations and possible injury of the furnace lining.

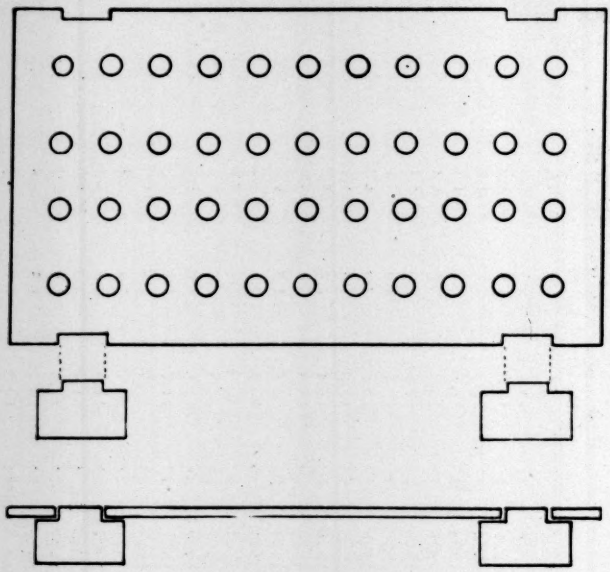

Fig. 1. Construction of Shelf and Supports.

Asbestos board, $\frac{3}{16}$" thick, with $\frac{1}{4}$" perforations to permit free circulation of air, and fitted to the inside dimensions of the furnace, serves for the floor of the shelf. Four narrow strips of similar asbestos board fitted to the shelf edges with dove-tail joints serve as supports and firmly hold the shelf in position. The diagram illustrates the design and fitting of parts.

RELATION BETWEEN CRUDE PROTEIN CONTENT AND LOAF VOLUMES OBTAINED BY TWO DIFFERENT METHODS OF BAKING

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(Received for publication April 23, 1930)

The quality of wheat is largely determined by reference to external appearance. This method of grading is valuable for purposes of estimating the probable yield of flour, freedom from defect or unsoundness, etc. However, this method is but an approximation, and practically all mills of any size in America accept or reject their wheat on the protein content basis as fixed by nitrogen determinations. The strength of the blended mix of wheat going to the rolls each day is governed in a similar manner.

Little direct evidence is available regarding the relation of the protein quantity of wheat to the baking strength of the resultant flour as milled in a commercial mill. This is due to the fact that the miller attempts to keep his mix at a uniform protein level to insure an even protein content in his flour. That such a relation exists, however, appears certain on account of the universal demand for high gluten content in flours for bread-manufacturing purposes. In order to determine this relationship, recourse must be had to the experimental mill.

In experimental milling about 2 kg. of wheat are milled into flour by a process not essentially different from that of a commercial mill, and the flour is comparable to commercially milled flour of the same extraction. Thus the relation between protein content and baking strength of the two flours should be the same. The correlations reported by Zinn (1923), Mangels (1926), Blish and Sandstedt (1925), and Bailey and Sherwood (1926) between these two variables, appear of rather low magnitude. Larmour and MacLeod (1929) published results of a series of baking tests using both bromate and basic methods, obtaining much higher correlations when bromate was used in the formula. It was, therefore, thought desirable to include a formula containing an improver in addition to the usual baking formula in determining the baking value of the 1929 wheat crop to determine if a strong correlation existed between protein content and baking strength. The knowledge of the reaction towards improvers of flours milled from wheats of various origins, as well as protein contents, would also be highly desirable, as bakers almost invariably employ them in some form.

The samples, consisting each of about 6 lbs. of wheat, were drawn from various carload lots at the time of unloading. These particular cars were chosen chiefly for diversity of origin and range in protein content. The wheat, when received at the laboratory, was cleaned by passing repeatedly through a separator until the dockage had been removed. It was then tempered and milled. Protein and moisture tests were run on the wheat as well as on the flour milled therefrom. The wheat moisture was determined on a Brown Duvel electrically-heated moisture tester; the flour moisture by heating in an air oven for one hour at 130°C. Ashing was done overnight at dull redness.

A two-roll Allis Chalmers experimental mill was used for the milling. The wheat was brought to a moisture content of 15% some hours before milling. A 75% patent flour was produced, the clear flour being discarded as the inclusion of the lower grade stock would only impair the quality of the flour and might lessen the applicability to commercial practice of the conclusions drawn from the tests. These flours were all bleached by an application of Novadel equivalent to a dosage of one pound to 45 barrels before baking or analyzing. The bleaching was accomplished through the agency of a suitable apparatus, insuring a thorough incorporation of flour and reagent.

The baking procedure used was a slightly modified form of the "Basic Standard Procedure" described by Blish (1928). Fermentation and proofing times and temperatures were according to the Blish method. The doughs were hand mixed in specially made earthenware bowls, the dimensions of which were: Height 4¼ in., diameter 5 in. and thickness of wall ¼ in. The following formula was used:

Flour	100 g.
Yeast	3 g.
Sugar	2.5 g.
Salt	2 g.
Water as required for proper consistency	

The salt and sugar solution as well as the water were added from a burette. The yeast suspension was measured in a 10 cc. graduated cylinder. All solutions were corrected for volume of solute contained therein. The doughs were run in pairs at intervals of 5 min. and were punched, panned and handled throughout in pairs. In mixing, 125 "cuts" were made with the spatula, then the dough was folded 20 times in the hands before placing in the lightly greased bowl, covered, and the bowl placed in the fermentation cabinet. Eight folds were made at first punch, 5 at second,

to prevent overworking the doughs due to greater depth of bowl as compared to those used by Blish. No attempt was made to bake at a constant absorption as such a proceeding would have been practically impossible in the range of flour studied. The baking was done in low tins of the following dimensions: Top 10 x 6.3 cm., Bottom 7.5 x 4.3 cm., Depth 4 cm.

In computing the baking score for each flour, the following method was used:

Loaf volume—x 0.1	
Symmetry—x 1	Maximum value—10
Grain of loaf (thickness of cell wall)—x 1	Maximum value—10
Color of loaf—x 1	Maximum value—20
Texture (feel and spring)—x 1	Maximum value—10

These individual scores were then added, the sum being the baking value of the flour. This system was used to bring into consideration the chief characteristics of the loaf, expressing the final results in a single value.

In this study, it was thought that the loaf volume figure alone would give a fairly true representation of the baking value of the various flours since not only is it by far the largest single score in the system mentioned, but it is free from influence of color fluctuations. While color is an important factor in commercial valuation of flour, it has not been shown to affect the strength and therefore in a study of strength only, it is not significant.

Following the method used by Larmour and MacLeod (1929) the bromate differential test was applied to these flours in a slightly modified form. One milligram of potassium bromate and 1% of diastatic malt were added to the basic formula and the flours rebaked. The response to this treatment as found by Larmour and MacLeod can be grouped roughly into three classes:

I. Those responding negatively.
II. Those exhibiting little or no effect.
III. Those showing a significant positive response.

In this study, a significant positive response is an increase of 4% or more. It was also found by these workers that further stimulation could be effected with those flours showing a positive response of over 10% with bromate and malt, by treatment with 0.5% Arkady and 3% malt. This formula is rather drastic and requires a fairly high protein flour to react favorably with it. Weak flours, containing less protein, fall down badly under Arkady and malt and are unable to withstand the sudden inflation due to increased evolution of gas during the first few minutes in the oven. The baked

loaf in these cases shows evidence of harsh treatment, such as a light, yellowish crust color, cracks in the crust, and holes in the interior of the loaf.

The potassium bromate was added by means of a 1 cc. pipette, each cc. of solution containing one milligram of the bromate. The Arkady was added in 10 cc. portions, each portion containing 0.5 grams of the improver. The malt was introduced as a solution, 12 cc. of which contained 3 g. of malt and 10 cc. of distilled water.

TABLE I

DESCRIPTION OF WHEAT SAMPLES

No.	Grade	Weight Per Bu.	% Crude Protein	No.	Grade	Weight Per Bu.	% Crude Protein
1	3° Poor	59	12.4	36	1°	64½	15.1
2	3°	59	12.2	37	1°	61	12.2
3	1°	64	12.5	38	1°	63	12.7
4	2°	64	14.8	39	1°	61½	14.3
5	1° Good	64½	13.8	40	2°	62½	14.8
6	2°	64	13.2	41	1°	63½	13.5
7	2°	62	13.8	42	2°	61	14.3
8	1° Very good	66	14.4	43	3°	57	16.5
9	2°	62	14.8	44	2°	60	16.5
10	1°	64½	12.4	45	2°	63	12.8
13	2°	60	16.7	46	2°	61	14.2
14	3°	62	15.3	47	2°	61	14.5
15	1°	66	11.7	48	1°	63	16
16	2°	55	16.2	49	1°	65	14
17	2°	62	11.4	50	1°	61	15.2
19	2°	64	12.6	52	2°	62	13
20	3°	64½	13.2	53	2°	61	12.95
21	1°	62½	13.1	54	1°	61	12.5
22	1°	62	14.3	55	1°	61½	13.1
23	2°	62½	12.6	56	1°	63	13.7
26	1°	60½	13.6	57	1°	61	13.5
28	1°	64	11.8	58	2°	60½	12.7
29	1°	63	16.9	59	1°	62	13.4
31	2°	59	15.6	60	1°	62	13.3
32	2° Tough	61	13.4	61	2°	65	9.9
33	2°	63	12.2	62	2°	64	12.1
34	1°	64½	12.3	63	2°	63	10.4
35	2°	61½	16.4	64	1°	64	11.8
				65	1°	61½	15.9

In Table I, a description of the wheat samples is given showing the grade assigned by a government inspector, the weight per measured bushel, and the crude protein content. It will be noted that the majority of the samples fall into grades 1 and 2; the remainder are all 3 Northern, there being no lower grades received in carload lots. There was no evidence of frost damage and only one sample graded tough. There was a considerable range in weight per measured bushel, from 55 to 66 lbs. Little if any rela-

tionship between grade and bushel weight is evident from inspection of the data.

The protein range is from 9.9 to 16.9%, and does not appear to be significantly related to either grade or test weight. A positive correlation of $r = + .9359 \pm .0111$ was obtained between the protein content of the wheat and the protein of the 75% patent flour milled therefrom, this justifying the popular belief that a strong protein wheat will produce a strong protein flour. No. 8 was a particularly fine appearing sample having a remarkably high test weight. While such a wheat will produce a high flour percentage when milled, the resultant flour for baking purposes was not so good as flour milled from a higher protein, lower grade wheat as No. 13, which graded 2 Northern and only had a weight of 60 lbs. per measured bushel. Two samples, Nos. 61 and 63 were outstandingly low in protein and gave flour which baked into loaves of very poor volumes and low baking scores. No. 61 was the poorest sample of the lot in baking strength, although it had a high test weight. It also had the lowest protein content (9.9%).

The baking and analytical data of the flours (75% patent) milled from these wheats are shown in Table II. The volumes and baking scores, it will be noticed, are given for two baking methods for each flour, as well as the differences in volume between the loaves obtained with the two methods and the per cent increase in loaf volume of the improver formula over that of the basic systems alone. The volumes and scores shown in the table were the maximum ones obtained, either with the use of 1% malt and 0.001% $KBrO_3$, or with 3% malt and 0.5% Arkady. When Arkady was used, the corresponding volumes obtained with 1% malt and 0.001% $KBrO_3$ are shown in Table IV.

It is clearly evident that the stronger flours of relatively high protein content give a surprising increase in volume under stimulation of bromate or Arkady, while the lower protein flours give a very much lower positive response, or else a falling off. An outstanding example of the first type is No. 25, giving a positive increase in loaf volume from 529 to 730 cc. and a change in baking score from 85.9 to 114. Similarly, Nos. 5, 43 and 44 show a marked increase in loaf volume, the volumes obtained corresponding to the protein content of the flour, whereas the basic method gives volumes increasing in magnitude with decrease in protein quantity. The low flours, as Nos. 61 and 63, show no such stimulation; No. 61 shows a falling down (evidence of weakness) under the improver and No. 63 remains practically the same being evidently incapable

TABLE II

BAKING RESULTS WITH ANALYTICAL DATA OBTAINED ON FLOURS OF 1929 WHEAT CROP, INCLUDING TESTS MADE WITH USE OF BASIC AND IMPROVER FORMULAE. PROTEIN AND LOAF VOLUME CORRECTED TO 13.5% MOISTURE BASIS

Lab. No.	Protein	Moisture	Ash	Absorption %	Loaf Vol. cc.	Symmetry	Color	Grain	Texture	Baking Score	Difference * B-I	% Increase Loaf Vol.
					*B 540	9	17	8	9	96.7		
A1	12.0	12.5	.352	60	*I 535	9	18	9	10	99.5	−5	−.92
					B 475	5	16	8	9	85.5		
A2	11.5	12.2	.355	60	I 515	6	17	9	9	92.5	40	8.42
					B 450	5	17	9	8	84.0		
A3	11.0	12.5	.415	59	I 440	5	18	10	9	86.0	−10	−2.2
					B 455	**5**	**17**	**8**	**9**	**84.5**		
A4	12.6	12.6	.360	59	I 555	7	18	10	9	99.5	100	21.98
					B 465	8	18	9	9	90.5		
A5	11.9	12.1	.350	59	I 515	9	19	10	10	99.5	50	10.75
					B 470	5½	18	9	10	88.5		
A6	12.0	12.96	.348	60	I 500	7	19	10	10	96.0	30	6.4
					B 440	6	16	9	9	83.8		
A7	11.7	12.4	.390	60	I 475	8	17	11	10	93.5	35	−7.9
					B 490	7	18	9	9	92.0		
A8	12.1	12.8	.340	61	I 500	8	19	10	10	97.0	10	2.04
					B 475	8	17	8	9	89.5		
A9	12.9	13.2	.345	60	I 560	8½	19½	10	9	103.0	85	17.9
					B 465	5	17	8	8	84.5		
A10	11.3	13.4	.330	60	I 465	5	15	9	9	84.5	0	0.
					B 520	9	17	8½	9	95.5		
A13	14.7	12.96	.395	60	I 680	11	21	10	9	119.0	160	30.8
					B 525	9	18	9	9	97.5		
A14	15.2	12.3	.403	61	I 650	11	18½	10	10	114.5	125	23.8

* B = basic formula; I = basic formula plus improver.

TABLE II—CONTINUED

Lab. No.	Protein	Moisture	Ash	Absorption %	Loaf Vol. cc.	Symmetry	Color	Grain	Texture	Baking Score	Difference * B-I	% Increase Loaf Vol.
					B 450	7	18½	9	8	87.5		
A15	10.5	12.8	.400	61	I 455	8	17	10½	8	89.0	5	1.1
					B 500	8	19½	8	9	94.5		
A16	13.1	12.3	.397	61	I 550	10	21	11	10	107.0	50	10.0
					B 445	5	15	8	8	80.5		
A17	10.15	13.2	.417	60	I 470	8	19	9	8	91.0	25	5.6
					B 443	5	13	8	7	77.0		
A19	11.2	13.4	.383	60	I 500	8	14	9	9	90.0	57	12.8
					B 463	6	17	9½	9	87.5		
A20	11.35	13.4	.383	61	I 560	9	17	9	10	100.5	97	20.9
					B 446	7	13	8	8	80.6		
A21	11.5	13.6	.420	60	I 490	9	16	9½	9½	93.0	44	9.8
					B 500	8	16	9	8	91.0		
A22	12.9	12.7	.417	60	I 525	9½	19	10	9½	100.5	25	5.0
					B 487	7	14	8	8	85.7		
A23	10.4	13.8	.360	60	I 520	8½	16	10	10	96.5	33	6.8
					B 502	8.5	12	7	6.5	84.2		
A24	12.75	13.6	.410	59	I 610	10	16	10	9	106.0	108	21.5
					B 529	7	12	7	7	85.9		
A25	16.0	13.7	.405	60	I 730	11	13	9	8	114.0	201	37.9
					B 472	5.5	17	8.5	8.5	86.7		
A26	12.6	13.2	.440	60	I 620	10	18	11	9	104.0	148	31.3
					B 500	8½	19	9	11	97.5		
A28	10.4	12.8	.383	61	I 505	8½	19½	11	10½	100.0	5	1.0
					B 520	9	17	8	9	95.0		
A29	13.8	11.1	.415	61	I 670	11	21	10½	10	119.5	150	28.8

* B = basic formula; I = basic formula plus improver.

TABLE II—CONTINUED

Lab. No.	Protein	Moisture	Ash	Absorption %	Loaf Vol. cc.	Symmetry	Color	Grain	Texture	Baking Score	Difference * B-I	% Increase Loaf Vol.
					B 525	9	13	9	9	92.5		
A31	13.6	12.7	.380	60	I 615	9	16	10	9½	106.0	90	17.1
					B 490	8	16	8½	8	89.5		
A32	11.5	13.1	.350	60	I 540	7	17	10	10	98.0	50	10.2
					B 505	7	15	8	7	87.5		
A33	10.6	13.8	.430	61	I 525	7	18	9½	9	96.0	20	3.9
					B 475	6	16	10	10	89.5		
A34	10.7	13.2	.385	61½	I 510	5	16½	10	9½	92.0	35	7.3
					B 545	9	18	9	9½	100.0		
A35	14.2	13.0	.368	60½	I 630	11	19	11	9	113.0	85	15.6
					B 534	8	15	9	9	94.4		
A36	13.4	13.6	.370	60½	I 605	9½	15½	10½	10	106.0	71	13.3
					B 490	8	17	9	9	92.0		
A37	11.0	14.1	.370	61	I 540	9	19	10	9½	101.5	50	10.2
					B 507	8	19	8	8	93.7		
A38	10.8	13.4	.370	61	I 516	9	19	10	10	99.6	9	1.7
					B 530	9	18½	9½	9	99.0		
A39	12.8	13.1	.420	61	I 552	10	19½	10½	11	106.2	22	4.1
					B 505	9	18	10	10	97.5		
A40	12.2	13.1	.387	60½	I 530	9	20½	11	11	104.5	25	4.9
					B 495	9½	19	9½	9	96.5		
A41	12.5	13.2	.415	61	I 558	9	20	11	11	106.8	63	12.7
					B 515	9½	17	9½	9	96.5		
A42	12.4	12.96	.358	61	I 580	10	19½	10	10	97.5	65	12.6
					B 505	8	12	6	6	82.5		
A43	14.7	12.3	.470	60½	I 644	11	17½	9	9	110.9	139	27.5

* B = basic formula; I = basic formula plus improver.

TABLE II—CONTINUED

Lab. No.	Protein	Moisture	Ash	Absorption %	Loaf Vol. cc.	Symmetry	Color	Grain	Texture	Baking Score	Difference * B-I	% Increase Loaf Vol.
					B 535	9	17	8	8	95.5		
A44	14.5	13.2	.388	61	I 650	11	19	10	9	114.0	175	21.5
					B 450	5	19	8	8½	85.5		
A45	10.5	12.6	.455	61	I 490	5½	16	8½	9	88.0	40	8.8
					B 485	7	12	5	7	79.5		
A46	12.4	12.6	.438	61	I 660	11	15	9	8	109.0	175	36.08
					B 517	7½	15	8	8	90.2		
A47	12.6	12.96	.505	60	I 560	10	19	9	9	103.0	43	8.3
					B 490	7½	17	8	8	89.5		
A48	13.3	12.9	.445	60	I 600	10	19	10	10	109.0	110	22.4
					B 505	7	18½	10	10	96.0		
A49	11.6	12.96	.410	60	I 540	8	20½	9½	10	102.0	35	6.9
					B 515	9	18	8	9	95.5		
A50	13.4	12.6	.410	61	I 620	10½	19	9	9	109.5	105	20.3
					B 485	6	17	8	9	88.5		
A52	11.5	12.96	.370	61	I 555	7	17	9	9	97.5	70	14.4
					B 485	8	17	10	9	88.5		
A53	11.5	13.76	.362	60½	I 590	6	18	10	9	102.0	105	21.6
					B 460	7½	17	8	8	86.5		
A54	11.0	14.1	.357	61	I 493	9	18	9	8	93.3	33	7.1
					B 492	7½	19	8	9	92.7		
A55	11.2	13.3	.380	61	I 540	9	20	10	10	103.0	48	9.7
					B 500	8	20	8	9	95.0		
A56	12.5	13.76	.350	60	I 620	11	21	11	11	116.0	120	24.0
					B 490	9	17	9	9	93.0		
A57	11.9	14.1	.375	61	I 595	8	17	9	9	102.5	105	21.4

* B = basic formula; I = basic formula plus improver.

TABLE II—CONTINUED

Lab. No.	Protein	Moisture	Ash	Absorption %	Loaf Vol. cc.	Symmetry	Color	Grain	Texture	Baking Score	Difference * B-I	% Increase Loaf Vol.
					B 500	8	18	8	9	93.0		
A58	11.4	14.5	.345	61	I 582	11	21	10	10	110.2	82	16.4
					B 525	9½	19	9	10	100.0		
A59	11.8	13.9	.365	61	I 577	11	20	10	9	107.7	52	9.9
					B 505	8	19	9	9	95.5		
A60	11.7	12.96	.390	62	I 545	10	21	10	9	104.5	40	7.9
					B 445	4	14	5	5	72.5		
A61	9.0	13.76	.530	62	I 410	3	13	5	4	66.0	−35	−7.8
					B 470	5	16	6	6	80.0		
A62	11.2	14.7	.410	62	I 490	5	17	7	8	86.0	20	4.2
					B 435	5	14	4	5	71.5		
A63	9.1	13.9	.450	61	I 440	5	13	4	3	69.0	5	1.1
					B 475	6	14	6	7	80.5		
A64	10.8	14.56	.343	62	I 510	7	15	7	7	87.0	35	7.3
					B 505	8	16	8	7	89.5		
A65	13.9	14.2	.365	60½	I 625	11	18	10	9	110.5	120	23.7

* B = basic formula; I = basic formula plus improver.

of further improvement. Flours Nos. 26 and 34 show a difference in protein content of nearly 2%, but give practically identical loaf volumes by the basic method. Under the action of an improver, however, the stronger protein flour gives a loaf 110 cc. larger in volume.

TABLE III

COMPARISONS OF LOAF VOLUMES OBTAINED WITH BASIC FORMULA, BASIC FORMULA + 0.001 $KBrO_3$ AND BASIC FORMULA WITH 0.5 ARKADY + 3% MALT

No. Sample	Loaf Volume		
	Basic	Basic + 1% Malt + 0.001% $KBrO_3$	Basic + 3% Malt + 0.5% Arkady
13	520	[illegible]	[illegible]
14	525	625	650
20	4[illegible]		
24	502	580	610
25	529	690	7[illegible]
26	472	560	620
29	520	640	670
31	525	615	615
35	545	620	630
43	505		
44	535	[illegible]	[illegible]
48	490	560	600
50	515	580	620
52	485	530	555
53	485	520	590
56	500	595	620
57	490	560	595

TABLE IV

AVERAGE PROTEIN CONTENT AND AVERAGE LOAF VOLUMES OF FLOURS ARRANGED IN GROUPS ON THE BASIS OF PROTEIN CONTENT

Crude Protein		Average Loaf Volume	
Range %	Average %	Basic cc.	Improver cc.
9-10	9.0	442	442
10-11	10.9	477	500
11-12	11.44	475	527
12-13	12.48	496	564
13-14	13.5	512	612
14-15	14.5	526	651
15-16	15.2	525	650
16-17	16.0	529	730

Figure 1 is a dot diagram of the basic loaf volume and flour protein content for the 59 samples. Figure 2 is a dot diagram for the improver loaf volume and protein content of the same samples. The regression lines have been calculated from the formula $x = (\bar{x} - r_{xy}\frac{\sigma x}{\sigma y}\ \bar{y}) + r_{xy}\frac{\sigma x}{\sigma y}\ y$ and drawn into the diagram. The data resulting from the baking tests and the protein determinations

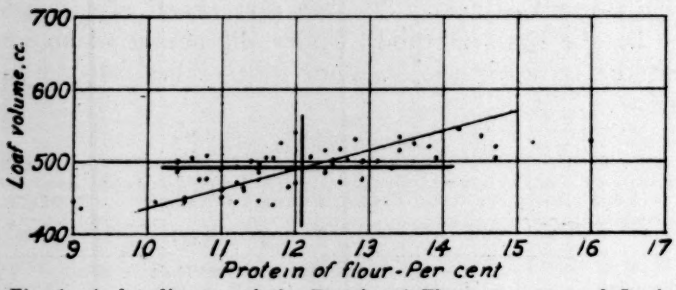

Fig. 1. A dot diagram of the Protein of Flour per cent and Loaf Volume (Basic).
$n = 59$, $r = +.6704 \pm .0483$

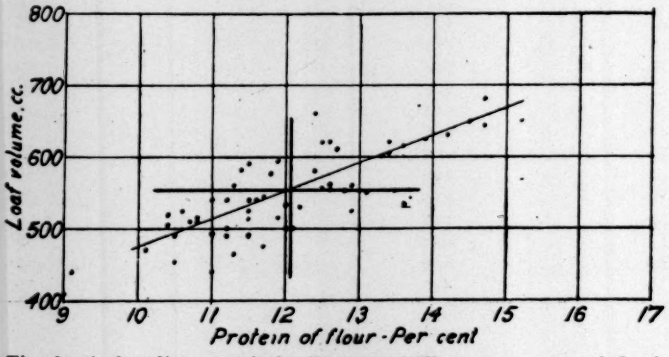

Fig. 2. A dot diagram of the Protein of Flour per cent and Loaf Volume (Improver Formula)
$n = 59$, $r = +.8571 \pm .0233$

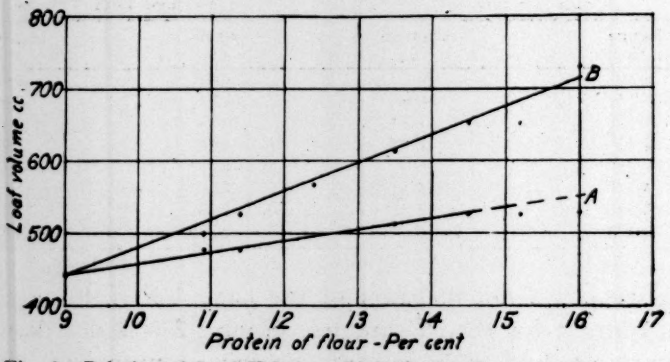

Fig. 3. Relation of Loaf Volumes obtained with Basic and Improver Formulae to Protein of Flour-per cent.
Curve A: Basic. Curve B: Improver

of these 59 samples were arranged in groups on the basis of protein content. All the samples containing less than 10% of crude protein were included in the first group, those with 10.0 to 10.9% in the second group and so on by 1% intervals to 15.9%. Only one sample fell into each of the groups 15.16 and 16.17. The average loaf volume obtained by both methods was then calculated. The data is shown in Table IV and depicted graphically in Figure 3.

Figure 1 represents in detail the data presented as curve A, Figure 3. An inspection of the diagram reveals no significant increase in loaf volume over a 4% range of protein, from 12% to 16%. Similarly there are no decreases in loaf volume of significance from 12.5% to 9% protein. The dots are distributed parallel to the base axis, and the probability of predicting loaf volume from protein content is not very great, the correlation coefficient between the variables being $r = + .670 \pm .048$. The points on curve A, Figure 3, when connected appear to lie on a straight line with the possible exception of the two last, in the 15-16% protein range. This may be due to there being only one sample in each of the groups 15 – 15.9% and 16 – 16.9% protein, or else curve A instead of being straight may be a section of a parabola.

Figure 2 is a dot diagram of the improver loaf volume and protein content of the same samples. Here, the distribution indicates a much stronger relationship between loaf volume and protein content, the loaf volume tending to increase fairly regularly with increasing protein. Curve B in Figure 3 shows the same data in a condensed form. The points lie on a straight line within experimental error, having a greater slope than curve A. The correlation $r = + .857 \pm 0.23$ indicates in this case a much greater probability of predicting loaf volume from protein content.

Summary

A study was made of 59 samples of Marquis wheat, grown in the territory more or less adjacent to Saskatoon. They were milled experimentally into a 75% patent flour and the flour baked by the basic method. They were also baked by a formula including 1% of malt and 0.001% $KBrO_3$. In the case of an increase of volume greater than 10% by the latter method, the samples were rebaked with 3% malt and 0.5% Arkady. Coefficients of correlation between baking strength and protein content obtained by the latter method were significantly higher and appeared to justify the conclusion drawn by Larmour (1930) that commercial use of the protein test is justified as a factor in the classification of hard red spring wheat.

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RELATION OF THE OVERGRINDING OF FLOUR TO DOUGH FERMENTATION [1]

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Since roller milling came into vogue there has been considerable discussion as to the relative importance of the size of the flour particle. Many flour millers are of the opinion that granulation is very important in producing quality flour, and some believe that the success of their particular brand is due to a definite degree of fineness which they have adopted as standard. It is generally conceded that the properties of flour may be altered by mechanical treatment. The nature and degree of this alteration has been made the subject of considerable study.

HISTORICAL

1. Granulation and Overgrinding

The investigations dealing with the effect of granulation of the flour on its chemical composition and baking quality may be divided into two main groups. One includes those examinations which were conducted in order to observe the behavior of the different sized particles of which flour is normally composed; the other, those in which the whole flour, ground to a definite fineness, or a definite number of times, was the subject of investigation.

Since it was not the aim of the writers to conduct further investigations that would belong to the first group, they should be mentioned here but briefly.

Richardson (1914) showed that flour containing a large proportion of granulates which pass through a No. 21 silk bolting cloth tends to lump and the baking quality was affected.

LeClerc, Wessling, Bailey and Gordon (1919) found that "the quality of the coarse and very fine portions or separates is inferior to that of the intermediate. In every case the quality of the bread made from the intermediate granulates is superior to that of the original flour." The very fine granulate was by far the poorest part of the flour, with respect to the quantity and quality of the gluten and the quality of the bread produced from it. The water absorption capacity paralleled the gluten content.

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Shollenberger and Coleman (1926) reported that the water absorption of the coarsest siftings was generally the highest, and that of the finest was the lowest. Bread possessed of the best grain and texture, greatest volume, and brownest and smoothest crust, was produced from the siftings of intermediate fineness. The color score appeared to be better in the case of the finer siftings, but in general these proved to be inferior as a bread flour. The differences in chemical composition were not significant.

The most recent investigations of this type were presented by Kress (1929). In his work the flours were divided into 8 portions, using Nos. 11 to 16 XX sieves for effecting the separations, and subjecting each sample to chemical and baking tests. He concluded that the most valuable part of the flour is that of medium granulations; the more even the granulation, however, the better the baking quality. It was further found, in contradiction to the statement that fine flour ferments faster than coarse flour, that "both fine and medium granular flour such as ordinarily made in good milling had practically the same rate of fermentation."

To the second group belong the investigations of Shollenberger, Marshall and Hayes (1921), of Alsberg and Griffing (1925) and in part those of Shollenberger and Coleman (1926).

Shollenberger, Marshall and Hayes (1921) investigated the effect of "grinding to different degrees of fineness" on the baking quality of flour.

Alsberg and Griffing (1925) reduced the materials in two ways. In the first case the flour was ground to four different degrees of fineness, but as in the investigations of Shollenberger, Marshall and Hayes, every sample contained the whole flour, reduced to a given degree of fineness. In the second case the flour was ground in a porcelain ball mill with flints for 36 and 53 hours, respectively. In consequence of the latter treatments the flours were much more finely distintegrated than by the former. They concluded that "overgrinding flour injures the starch granules so that part of the starch swells and disperses when the flour is doughed." One result is an increase of cold water extract from dispersed starch. This was first observed by Wanklyn and Cooper (1881). "Another result is increased diastatic starch conversion in the flour from which an increased initial rate of fermentation follows. Severe overgrinding injures flour for baking purposes despite increased absorption due to swelling of starch granules. Evidence is presented that it also injures the gluten. Moderate overgrinding may injure the starch granules without much affecting the gluten."

Shollenberger and Coleman (1926) found that when flours were ground a number of times or to a certain degree of fineness, "the doughs of the finest ground materials were in some instances inclined to be sticky and weak. The excessive grinding showed some tendency to slow up the rate at which the flour absorbed water, but the total quantity absorbed increased very markedly and consistently with the number of times of grinding." As to the color and grain of the crumb, the best scores were from materials treated the least. The texture was little affected. No very pronounced alteration in the color and condition of the crust was noticeable. They found further that the cold water extract and the diastatic power increased progressively with excessive grinding.

2. Saccharogenic Activity

It has been indicated that certain investigators observed that the "diastatic" or "saccharogenic" activity (as proposed by Bailey, 1925) of the flour is substantially increased by overgrinding.

Pascoe, Gortner and Sherwood (1930) maintain also that the saccharogenic activity of the flours is largely influenced by the degree of granulation. The autolytic saccharogenic activity of an aqueous suspension of a flour sample milled in the commercial mill and reground in a ball mill for twenty hours was increased approximately 35%. They state that without extended fermentation periods the basic procedure does not permit detection of flours low in saccharogenic activity from loaf volume values, evidently because during the relatively short fermentation period the added sugar is sufficient for the nutrition of the yeast.

Rumsey (1922) believed that "the flour showing the greater diastatic power should show the greater strength and consequently the greater baking value, providing the relative quality and quantity of the gluten is the same." It is logical therefore that at least in certain cases attempts should be made to supplement the diastatic power.

Collatz (1922) indicated that "in all cases the use of malt extract gave a superior loaf of bread in volume, grain and texture, thus increasing the baking strength of the flour." "Addition of diastatic ferments converts the starch to reducing sugars and in the earlier stages of fermentation produces surplus of fermentable sugars in the doughs made from strong flours. This surplus soon disappears as the activity of the yeast increases." "The strong flours showed a higher sugar content and greater diastatic activity than did the weaker flours. The starch of the strong flours ap-

peared to be more easily hydrolyzed by diastatic ferments than that of the weaker flours."

Sherwood and Bailey (1926) showed how diastatic activity can be increased by the addition of small quantities of germinated wheat. The length of the germination period was found to be important. Large quantities of germinated wheat effected a reduction in baking value which probably could be attributed to the activity of proteases.

Mangels (1926) reached the conclusion that "the diastatic activity of flour as measured by Rumsey's method is the result of the combined effect of diastase concentration and the relative susceptibility of the starch of the flour to diastase attack. The variation in diastatic activity of flour appears to be due in large part to the susceptibility of the starch granule to diastase attack, rather than to the concentration of diastase present."

Malloch's (1929a, 1929b) investigations further emphasized the necessity for distinguishing between the resistance of the starch to diastatic action and the actual activity of the diastatic enzymes in studying the saccharogenic power of flour-water mixtures.

It was shown by Brown and Heron (1879) and Maquenne (1904) that mechanically injured starch granules are more readily attacked by diastase.

Bailey (1925) states "that two advantages accrue from a fairly high diastatic activity of bread doughs. The first involves the maintenance of a fairly constant and reasonably high sugar level. The second involves the economy which results from using starch of the flour as the source of fermentable sugars, since the sugar required for the yeast is obtained more cheaply from flour starch than from added sugar."

Blish and Sandstedt (1925) and later Blish, Sandstedt and Platenius (1929) found a high positive correlation between crust color and diastatic value, if the flours were baked by the basic method, and they believe that in this method crust color furnishes an indication of diastatic value almost as useful as a direct determination of the latter.

Martin (1920) demonstrated that if the gas-producing capacity of the flour is not satisfactory, the deficiency can be rectified by the addition of a diastatic preparation.

3. Gas Production and Gas Retention

The success of the conversion of the flour into superior yeast leavened bread depends largely on its gas-producing and gas-retain-

ing capacity. The first of these seems to be closely related to the saccharogenic activity.

Wood (1907) reaches the conclusion that: "The rate of gas evolution and size of the loaf run parallel, and it seems certain, therefore, that it is more particularly the gas given off in the later stages of dough fermentation that determines the size of the loaf. This being so the size of the loaf will depend, not so much on the sugar present in the flour as such, as on the diastatic capacity, which will cause continued sugar formation and consequently continued gas evolution in the dough."

Baker and Hulton (1908) said: "It is certain that some of the carbon dioxide concerned in the rise of bread, especially in the later stages of doughing and in the earlier period of baking, is formed from the fermentation of the maltose produced by the action of the diastase on the flour starch." The general conclusion of Baker and Hulton was that gas retention appeared to be a more important factor than gas production.

Humphries and Simpson (1909) suggested that it is the gas evolved in the latter stages of fermentation which is the more important factor.

Martin's work (1920) is in effect a continuation of that of Wood. He found that "neither the total gas nor the amount liberated during the proving period determines the size of the loaf, yet in order to obtain a large loaf an adequate supply of gas must be available, but that a deficiency of gas can be rectified by the addition of suitable diastatic preparations." "The amount of gas retained by the doughs varies with the percentage of gluten in the dough," and "there is a marked difference in the gas retaining powers of the glutens from various sources."

The difficulty of using the expansion (volume) of a dough as a measure of diastatic capacity is due to the weakening of the gluten after the second or third hour. "Curves plotted to show the relation between the amounts of gas generated and the volumes of the doughs were fairly regular for the first part of the experiment, but erratic for the latter part, the irregularity coinciding with the appearance of holes in the surface of the doughs."

He states that a strong flour must possess a minimum gas-producing and high gas-retaining capacity, a statement which may be disputed by some American investigators.

Bailey (1916) described a method for measuring the gas production of the dough by means of a specially constructed expansimeter. He further suggested that instead of Humphries' and Bif-

fen's term: "a strong wheat is one which yields flour capable of making large, well-piled loaves" the following statement should be preferred: "The strength of the flour is determined by the ratio between the rate of production of carbon dioxide in, and the rate of loss of carbon dioxide from, the fermenting mass of dough."

A few years later Bailey and Weigley (1922) demonstrated that "the loss of carbon dioxide per unit increase in volume under controlled conditions affords a useful measure of the gas-holding capacity of dough." A procedure was described by means of which such data may be obtained for comparing different flours. They in addition made the interesting suggestion that "ripening of dough during fermentation may be in part the result of solution in the dough of carbon dioxide, which may later become available for expending the loaf when the latter is placed in the oven to bake."

Two different devices were described by Bailey and Johnson (1924) for convenient determination of the optimum fermentation period. These could be substituted for the accurate but too complicated method formerly developed by Bailey and Weigley (1922). In the first method, total dough expansion is determined and also dough expansion plus carbon dioxide loss. The difference registered represents the quantity of carbon dioxide which has escaped from the dough. The second device is the modification of the Osterhout apparatus, by which only the rate of carbon dioxide loss is determined. The values, however, are useful criteria of the stage of fermentation.

EXPERIMENTAL

The Problem. On studying the literature presented, it will appear that considerable work has been done to ascertain the effect of granulation and of different mechanical treatments upon the quality of flour. This has included some investigation of the influence of treatments upon the saccharogenic activity, and the gas-producing and gas-retaining ability of doughs made from flours so treated. Since observations regarding the gas production and gas retention have only been incidental to general effects caused by differences in particle size and so far as we are aware have not been extensively investigated, we preferred to conduct a more definite study of the effect of overgrinding on the fermentation rate of flours of different origin. In addition it was desired to investigate whether differences in saccharogenic activity might be reflected in the gas-producing and gas-retaining ability of doughs

when overground and the corresponding untreated flours are compared.

Flour Samples

Four different flours were studied

No. 12228: Milled from a blend of both winter and spring wheats, possibly also containing some soft wheats. The sample was received from Washington, D. C., and contained 11.6% moisture, 0.37% ash and 9.8% protein.

No. 12428: The wheat mixture from which this was milled contained a high percentage of western white wheat. The flour was milled in Seattle, Wash., and contained 12.5% of moisture, 0.37% of ash and 10.2% of protein.

No. 12508: An 80% patent flour milled from a blend of spring wheats by the Minnesota State Testing Mill, containing 14.5% moisture, 0.45% ash, and 11.7% protein.

No. 12778: A bleached straight grade flour milled from a blend of hard spring wheats, with 13.5% moisture, 0.49% ash and 11.9% protein.

Methods

Overgrinding. For the preparation of the flours the experimental milling equipment was used. Two kilos of the commercially milled patent flour was first bolted through a 25XX silk sieve. The scalpings were ground between the smooth rolls, set as close as possible. After each grinding the material was bolted and the scalpings ground again. After having been ground and bolted twelve times, a very small part of the flour could not be reduced to the fineness wanted. This branny part was pulverized in a porcelain mortar, bolted and added to the overground flour. To make the flour uniform the whole was mixed very carefully, then bolted three times through a coarse sieve.

This procedure corresponds to that used by Shollenberger, Marshall and Hayes, by Alsberg and Griffing, and by Shollenberger and Coleman in a part of their investigations. The overground flour contained all of the original flour, nothing was taken away, and nothing added.

Saccharogenic Activity. For the determination of the saccharogenic activity Rumsey's procedure was used with slight modification as noted by van der Lee (1929). A 10 gram sample of the flour was weighed and transferred to a 250 cc. Erlenmeyer flask, which was placed in a water thermostat at 27°C. After attaining the

temperature, 70 cc. of distilled water of the same temperature was pipetted into the flask and the flask rotated and the lumps disintegrated by means of a small glass rod. The suspension was stirred up every 15 minutes. After 60 minutes digestion 3 cc. of 15% sodium tungstate was added followed by the addition of concentrated sulfuric acid until a drop of the suspension would turn a drop of a 0.04% thymol blue indicator a decided pink color. Then two or three drops of the acid were added in excess.

After rinsing into a 100 cc. volumetric flask the suspension was centrifuged for 5 minutes at high speed. The reducing sugars were determined at once in a 20 cc. aliquot of the clear solution by the method of Bertrand (1906).

The procedure for the determination of the blank was the same except that enzymic action was inhibited by sulfuric acid and clarification with sodium tungstate immediately after the addition of water to the flour.

Malloch's (1929a) remark that the sugars should be determined immediately after the centrifuging proved to be entirely justified; otherwise it is quite impossible to get reliable results.

From the weight of maltose in milligrams was subtracted the maltose equivalent of the blank and the difference in terms of maltose per 10 grams of flour was recorded as a measure of diastatic activity.

Gas production and gas retention. In preparing doughs for the gas production and retention tests, the following formula was used:

Flour	300 grams
Sugar	7.50 grams
(except in instance of sugar-free doughs)	
Salt	5.25 grams
Yeast	9.00 grams
Shortening	6.75 grams
Water	Sufficient

The doughs were mixed for 3 minutes in a Fleischmann mixer. Description of the further procedure will be found in the discussion of the gas experiments.

The method for studying the carbon dioxide diffusion ratio of doughs of the original untreated and overground flours was the same as described by Bailey and Johnson (1924) and will not be detailed here. The only two differences were that in the first place instead of inserting the beakers into a perforated waxed paper cylinder, the specially-made perforated glass beakers were used as developed later by St. John and Bailey (1929). In the second

place, since in certain cases the containers would not hold completely fermented doughs made with 50 g. of flour, the size of the dough was reduced to the equivalent of 40 g. of flour.

Saccharogenic Activity

The saccharogenic activity of the four flour samples both overground and untreated was determined by the method previously described. The values recorded in Table I were obtained.

TABLE I

INCREASE IN SACCHAROGENIC ACTIVITY OF FLOURS DUE TO OVERGRINDING

No.	Anhydrous Maltose in mg. by Diastase per 10 gm.		Increase
	Untreated	Overground	%
12228	82.3	121.3	47.4
12428	43.0	75.5	75.6
12508	66.5	100.9	51.7
12778	110.4	136.1	23.3

In accordance with the observations of other investigators the results contained in Table I clearly show that saccharogenic activity in an aqueous flour suspension is substantially increased by overgrinding the flour. The last column represents the percentage increases due to overgrinding. These data are of considerable interest. They seem to indicate that if the saccharogenic activity of the untreated flour is comparatively low, the increase is much more significant than if the original value is higher. Thus overgrinding flour No. 12428 increased it in this property by 75.6 per cent, while with No. 12778 the increase was only 23.3 per cent.

The increase in saccharogenic activity is not believed to be due to any stimulation of the diastase, but rather to an increase in accessibility of the starch to the diastase. Overgrinding increases this accessibility by making a greater percentage of the starch dispersable in water and also by freeing much of it which is imbedded in a gluten matrix in normally ground flour.

Gas Production and Gas Retention

Since overgrinding causes certain changes in the properties of flour, due to the alteration of the size of the particles and its effect upon the behavior of the components when the flour is subjected to external influences, it would seem reasonable to suppose that these changes would be reflected in the fermentation rate of doughs made from such flours. It might be presumed that as a

result of overgrinding the gas production and gas retention would be modified.

The fermentation rate of the different flours was studied through the use of different dough treatments. (1) The doughs were placed in the beakers immediately after mixing and the carbon dioxide generation observed for a 4 hour period; (2) the doughs, before placing them in the containers, were previously allowed to ferment for 3 hours by the regular procedure and then observed for 3 hours; (3) the doughs were treated in the same manner as (1) except that the sugar was omitted from the formula.

The tests were always made in duplicate in the same determination, doughs being mixed of both overground and untreated flours. After the doughs were inserted in the beakers for the gas tests, readings were made every 15 minutes.

The data representing the results of all of these experiments are expressed in the five graphs plotted with time in minutes as abscissas and volume in cc. as ordinates. The curves A represent the progressive expansion of the dough plus the volume of the escaping gas, i. e., the total carbon dioxide produced by the activity of the yeast. Curves B show the expansion of the dough. The difference between the values recorded in Curves A and B are recorded in Curves C which accordingly represent the volume of carbon dioxide that escaped from the dough. Curves in solid lines give the results for doughs made from untreated flours, and curves in broken lines record values obtained for doughs made from the corresponding overground flours. Curves at the left of figures 1 to 4, which extend through 240 minutes represent observations upon doughs immediately after mixing, while those at the right extending through 180 minutes represent aliquots of the same doughs which had been previously fermented for 3 hours.

The results from the first group of the experiments upon freshly-mixed doughs indicate that there are only small differences between the fermentation rate of the overground and untreated flours. The expansion plus carbon dioxide loss, and the carbon dioxide loss alone were in every case somewhat greater for the doughs made from overground flours. The dough expansion was greater in three out of four cases for the same flours, but the differences are not significant. Until about 90 minutes have elapsed, almost the entire quantity of carbon dioxide produced is retained in the doughs; total gas and dough volume curves nearly coincide to this point. From this time on the further expansion ceases and the volume of the dough remains almost constant throughout the

experiment, and the expansion curves are nearly a horizontal line. On the other hand at this stage the carbon dioxide loss increases rapidly, as indicated by the sharp break of Curves C.

When the results as expressed in all these curves are averaged, we find that the overground flours produced 12 cc. more gas than the untreated. Since the expansion of the former was 3 cc. more than that of the latter, this gives a 9 cc. greater carbon dioxide loss for the overground flours during the whole 4 hour period. In terms of percentages these values represent only an increased gas production of 2.60 per cent and an increased carbon dioxide loss of 1.95 per cent for the overground flours, which are probably too small to be of significance.

The ability of the dough to produce a good loaf of bread is chiefly dependent upon its gas-producing and gas-retaining capacity and condition after panning and when placed in the oven. To obtain the best picture of dough condition it would seem desirable to ferment it in the usual way and then to measure its gas-producing and gas-retaining capacity from the time it normally receives its last handling in the baking test. This might give a truer measure of the ability of a dough to rise in the pan and spring in the oven than a gas production test which begins at mixing time and continues for several hours with none of the kneadings usual in baking procedure.

After being mixed the doughs therefore were fermented at 30° C. for the usual 3 hours with the first punch at the end of 105 minutes and the second after an additional 50 minutes period. After the third period of 25 minutes, that is at panning time, aliquots of the doughs representing 40 g. of flour were placed in the beakers and the carbon dioxide diffusion rate determined through a 3 hour period.

Data recorded in Figures 1 to 4 show that the differences between overground and untreated flours, after 3 hours fermentation, are not more significant in this case than are shown in the experiments with freshly mixed dough. The carbon dioxide loss was greater and the expansion smaller to some extent for the doughs prepared from overground flours. This indicates that the rate of gas production is not as high after 3 hour fermentation as immediately after mixing. The break of the curves B and C makes its appearance after about 105 minutes, but the breaks are not as sharp as appear with freshly mixed dough.

The average gas production was 1 cc. greater, the expansion 5 cc. smaller, for the overground flours. This means that 6 cc. more

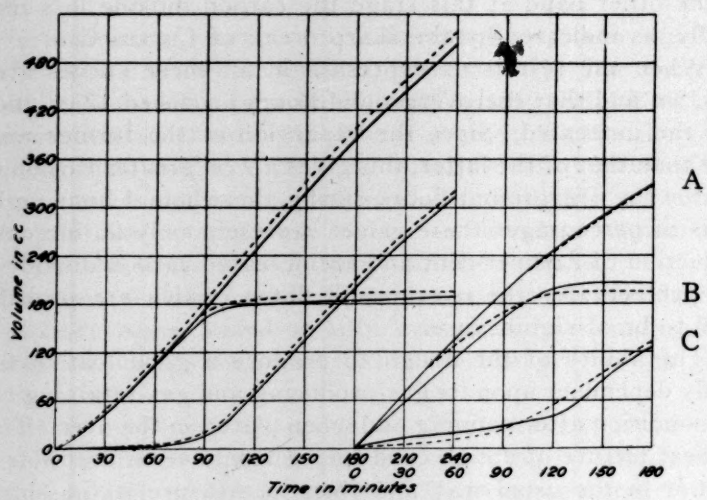

Fig. 1. Flour 12228

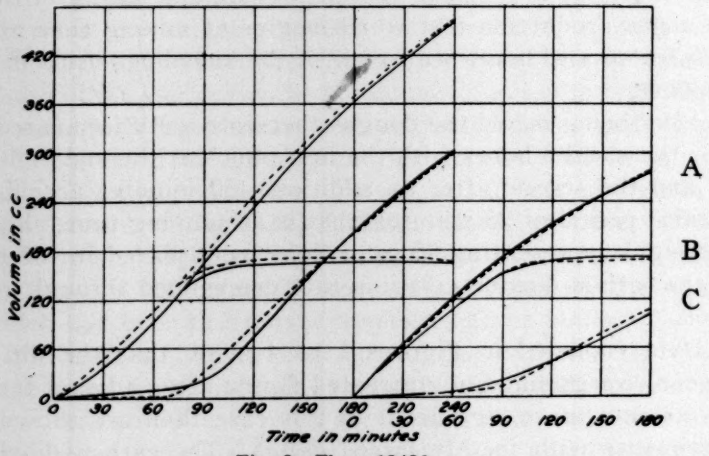

Fig. 2. Flour 12428

Figs. 1 and 2. Comparison of the fermentation of doughs mixed from Flours 12228 and 12428 before and after overgrinding. Curves A represent the sum of the increase in volume of the dough and the carbon dioxide lost from the dough; Curves B the increase in volume of the dough; Curves C the carbon dioxide lost from the dough. Curves starting at extreme left of figure represent observations upon freshly mixed dough; those starting after 180 minutes record observations upon doughs fermented for that length of time. Solid lines record data from the untreated flour doughs, broken lines from the same flour after overgrinding.

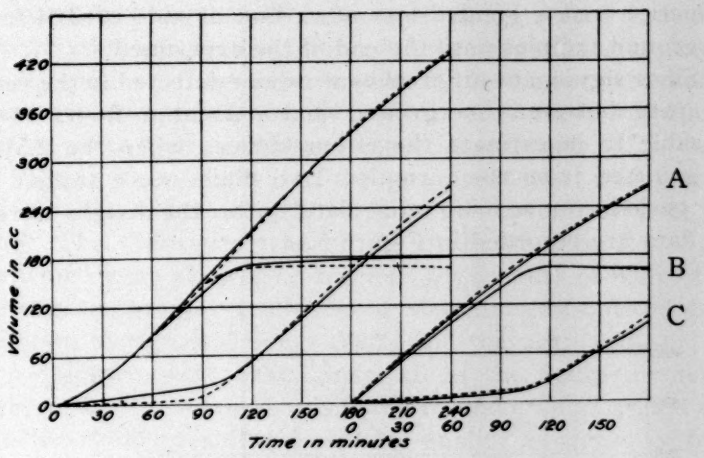

Fig. 3. Flour 12508

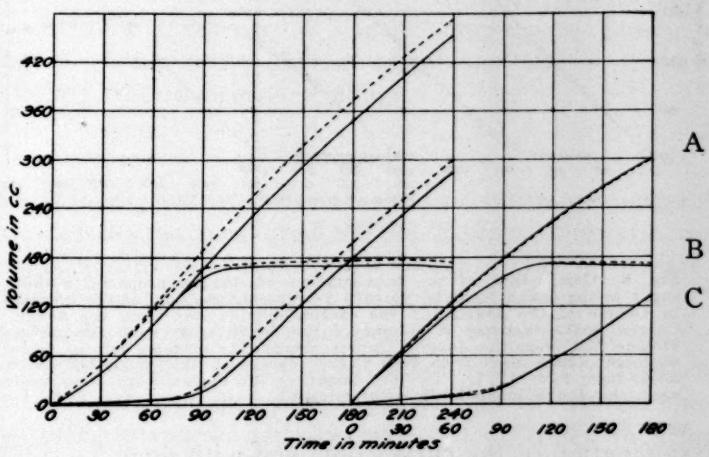

Fig. 4. Flour 12778

Figs. 3 and 4. Comparison of the fermentation of doughs mixed from Flours 12508 and 12778 before and after over-grinding. Curves A represent the sum of the increase in volume of the dough and the carbon dioxide lost from the dough; Curves B the increase in volume of the dough; Curves C the carbon dioxide lost from the dough. Curves starting at extreme left of figure represent observations upon freshly mixed dough; those starting after 180 minutes record observations upon doughs fermented for that length of time. Solid lines record data from the untreated flour doughs, broken lines from the same flour after over-grinding.

carbon dioxide escaped from the doughs made from such flours. Expressed in percentages these values show 0.34% increase in gas production and a greater loss of carbon dioxide of 2.04% for the overground samples until the end of the experiments.

Since significant differences were not detected in the fermentation rate between overground and untreated flours it seemed advisable to investigate the circumstances when the 2.5% sugar was omitted from the formula. Two flours were studied for a 4 hour period, commencing immediately after the doughs were mixed. The data are recorded in Figure 5.

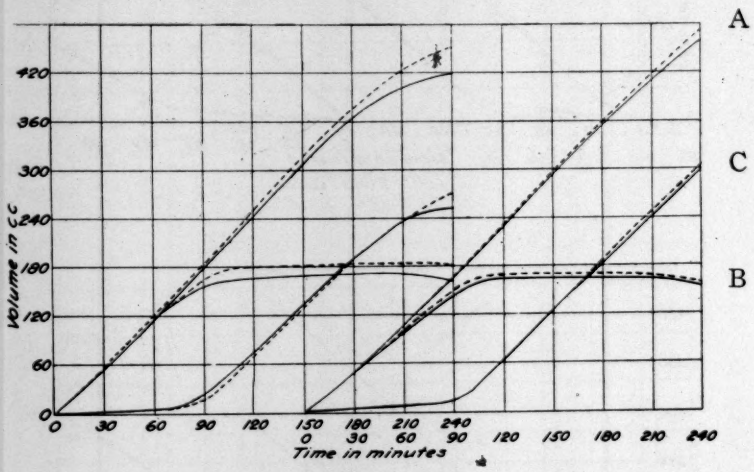

Fig. 5

Fig. 5. Comparison of the fermentation of doughs prepared without sugar in the dough formula. Curves A represent the sum of the increase in volume of the dough and the carbon dioxide lost from the dough; Curves B the increase in volume of the dough; Curves C the carbon dioxide lost from the dough. Curves starting at extreme left of figure represent dough made from flour 12428; curves at right represent dough made from flour 12778. In both instances the observations were made upon the dough immediately after mixing.

Examination of the curves obtained with flour No. 12778 indicates that omitting the sugar had no marked effect upon the fermentation of this flour. In the case of flour No. 12428, however, after about 200 minutes both carbon dioxide production and carbon dioxide loss was less in the untreated sample than in the overground. Previous to this decrease there had been very little evidence of any appreciable difference caused by overgrinding. This was a flour strikingly poor in saccharogenic power as previously shown.

All these observations are the more interesting because Als-

berg and Griffing (1925) in studying a Turkey red and a hard spring flour found that the carbon dioxide loss was much more rapid for the overground than for the corresponding untreated flour in the early part of fermentation. Since these investigators used the Osterhout method, they were unable to determine whether this increased evolution of carbon dioxide was due to a more rapid gas production or to a decreased gas retention capacity.

In mixing the doughs for the gas production and retention tests, a consistent increase in absorption was observed due to overgrinding. The difference was of the order of 3 to 5%. In the doughs which were allowed to ferment for 3 hours previous to the test, a slightly greater tendency to slacken was noticed in the doughs from overground flours than from the untreated.

A few loaves were baked from all of the flours involved in these gas tests. No attempt was made to make an extended study of the effect of overgrinding on baking quality as measured by the regular test baking procedure. The results secured were in general agreement with those obtained by other investigators. Aside from the increased absorption, which has already been referred to, the most marked effects of overgrinding were found in the tendency toward a more grayish crumb and darker crust in the loaves baked from overground flours.

Summary

Overgrinding wheat flours resulted in substantial increases in diastatic activity as measured by the Rumsey autolytic method. The magnitude of the proportional increase was in inverse ratio to the initial diastatic activity of the untreated flour.

Gas production and gas retention in freshly mixed doughs, and in doughs previously fermented for 3 hours were not substantially modified by overgrinding. This suggests that the Rumsey method for measuring diastatic activity may fail at times to afford an adequate basis for estimating the fermentation potentialities of a wheat flour when measured either in terms of gas production, gas retention, or fermentation tolerance.

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CONTRIBUTION TO THE KNOWLEDGE OF COLLOID CHEMISTRY OF GLUTEN. III.

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Acetone and Gliadin

In a former publication[1] the influence of varying alcohol concentrations on the viscosity of gliadin solutions was investigated. This paper will deal with the phenomena observed upon addition of acetone to gliadin solutions.

Just as gliadin dissolves easily in definite alcohol-water mixtures, so it does in definite acetone-water media. This can be explained by assuming that acetone reacts in aqueous solution (in regard to the hydration of the protein particle) as a polyhydroxy

[1] Cereal Chem. 7: 222-224 (1930).

alcohol, by addition of water to its C=O radical. Therefore it is to be expected that we will meet with practically the same phenomena in acetone media as in alcoholic media. However, it is desirable to discuss briefly the phenomena observed upon addition of acetone to gliadin solutions, because a great part of the investigations on the lyotropic influence of different electrolyte solutions are done in acetone-water mixtures. These researches will be published later.

First, the influence of acetone on the viscosity of a clear gliadin solution was investigated.

An optically clear gliadin solution was prepared by shaking 1.5 g. of gliadin with 4 cc. 0.1 N HCl and 51 cc. distilled water. Of this gliadin solution 2.5 cc. portions were diluted with different quantities of acetone and made up to mark (25 cc.) with distilled water at 25° C. in a thermostat. At the same time, acetone-water mixtures with the same acetone concentrations were made. The acetone used was rectified before the experiments. By dividing the viscosity values of the corresponding protein-acetone solutions and the acetone-water mixtures, the relative viscosity of the protein in these media was calculated.

Table I gives the results of our experiments.

In Figure 1 is plotted the curve of the relative viscosity with changing acetone concentration and the curve of relative viscosity of the same protein solution in media with different alcohol concentrations. These experiments indicate:

1. The viscosity of the acetone-water mixtures passes through a maximum at about 44% acetone by volume.
2. The viscosity of gliadin (acetone-water) mixtures passes through a maximum at about the same acetone concentration as the corresponding acetone-water dilution.
3. The relative viscosity of the protein solution increases until a concentration of about 44% acetone in solution is reached; after this a rapid fall takes place.

TABLE I

INFLUENCE OF VARYING ACETONE CONCENTRATIONS ON THE VISCOSITY OF AN ACID-GLIADIN SOLUTION

Acetone, cc.	0	3	6	8	10	11	12	15	20
η_{s+Ac}	....	1.376	1.630	1.756	1.834	1.847	1.834	1.683	1.024
η_{Ac+w}	....	1.232	1.443	1.543	1.600	1.606	1.600	1.479	0.9815
$\frac{\eta_{s+Ac}}{\eta_{Ac+H_2O}}$	1.104	1.118	1.129	1.138	1.147	1.149	1.147	1.138	1.043
Increase, %	....	13.4	24.0	32.7	42.1	44.0	42.1	33.3	58.8

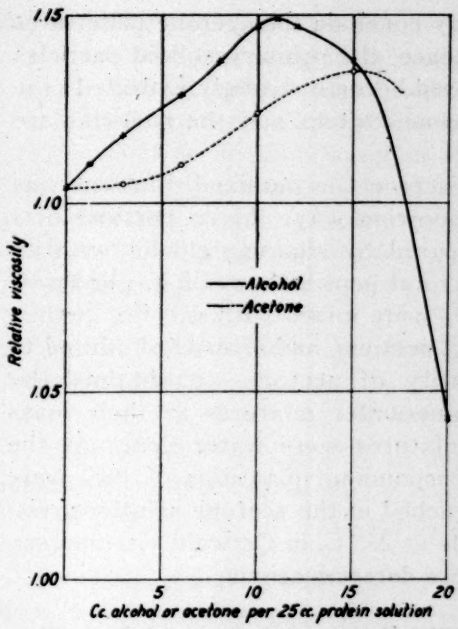

Fig. 1. Influence of varying acetone and alcohol concentrations on the relative viscosity of an acid gliadin solution.

The explanation of these phenomena is to be found in the fact that in contact with aqueous solutions of acetone containing less than 44% of acetone, the protecting layer of the particle increases because the acetone penetrates the original hydrate layer. Herewith is coupled a stabilizing effect on the system; in higher acetone concentrations the particle gradually loses its protecting layer, the emulsoid passes into a suspensoid, and the charge of the particle only remains as a stability factor (influence of traces of electrolyte, Tyndall effect, etc.)

By comparing the curves for relative viscosity in acetone and alcoholic media, the following are found: (1) While the relative viscosity curve in the alcoholic solution rises gradually, the acetone curve rises straight to its maximum. These differences can be caused either by the nature of the colloid surface or by a substance adsorbed on the surface. In the last case the differences between the two curves can be explained by assuming that acetone directly expels the adsorbed substance from the surface, while alcohol does the same gradually. (2) The per cent increase in viscosity at the maximum is larger for acetone than for alcohol, vis., the protecting layer in acetone medium at the maximum is larger than in 60% alcoholic solution; in other words, the stability is greater in acetone.

The influence of acetone on separated gliadin solutions was investigated. The same visible phenomena were found as in alcohol medium, the cloudy protein solution becoming water-clear by addition of acetone.

Microscopically, the following facts were established: By adding a trace of acetone to a separated solution with many protein globules, the globules begin to swell. By increasing the acetone concentration the drops lose their outline and the liquid becomes

optically void. From this we may conclude the acetone penetrates into the globules. As a consequence, the primary colloid particles of which the globules are composed become strongly hydrated (the protecting layer consists of acetone-water) and the particles are driven into colloidal solution.

The dispersing influence of acetone on unmixed solutions was viscometrically studied in the following way: 2.5 cc. portions of a separated protein solution, prepared by shaking gliadin with an insufficient quantity of acid for total peptization (1.5 g. gliadin + 1.5 cc. 0.1 N HCl + 53.5 cc. H_2O) were mixed with varying quantities of very dilute HCl and 11 cc. acetone, and afterward diluted to 25 cc. at 25° C. With this quantity of acetone we obtained (by changing the pH) gliadin-acetone-water mixtures at their maximum of viscosity. All these mixtures were water-clear. At the same time, hydrosols with corresponding quantities of HCl were made. After equilibrium was reached in the acetone solutions, viscosity determinations were made at 25° C. in Ostwald viscometers. Table II gives the results of these determinations.

TABLE II

INFLUENCE OF CHANGING ACIDITY ON THE MAXIMUM OF VISCOSITY OF A GLIADIN SOLUTION

0.01 N HCl, cc.	0	0.25	0.5	1.0	1.5	2.0	3.0	5.5	20.0	50.0
η_{s+w}	1.062	1.078	1.086	1.099	1.104	1.104	1.097	1.085	1.056	1.039
η_{w+Ac}	1.606	....	....	....	....	....	....	....	....	....
η_{s+Ac}	1.767	1.793	1.809	1.835	1.844	1.843	1.825	1.799	1.744	1.724
$\frac{\eta_{s+Ac}}{\eta_{w+Ac}}$	1.100	1.117	1.126	1.143	1.149	1.148	1.136	1.120	1.086	1.074
Increase, %	61	50	47	44	43	42	40	41	54	89

The relative viscosity of the sols at different concentrations of acid, calculated from these values, can be found in the fifth (horizontal) line, while in the sixth line appears the per cent rise in viscosity from the hydrosol at different concentrations of acid, by adding 11 cc. acetone. The last mentioned values decrease upon addition of acid until the point of maximum hydration of the colloid particle in the hydrosol is reached. After this point these values decrease slightly by changing the H-ion concentration to the acid side. Afterward, by addition of more acid, a strong increase occurs.

By plotting the values of the per cent rise against the viscosity of the corresponding hydrosols, a curve of the same shape as in alcohol medium results. The interpretation of these facts is the same as given in a previous paper in a study on the influence of alcohol on gliadin solutions. The large per cent rise at both sides

of the maximum indicates that two areas of separation exist.

From the preceding facts it appears:

1. That the influence of acetone on an acid gliadin sol is in the main the same as of alcohol.
2. That an acetone-water mixture containing about 44% acetone by volume is a good solvent for gliadin.

The acetone-water mixtures mentioned before can be used with profit for the preparation of gliadin from gluten on account of the great stability of the protein in this medium. Care must be taken that the extraction of gliadin takes place at a pH as near as possible to the isoelectric point of glutenin. This will be discussed in a later paper.

Summary

The relative viscosity of an acid gliadin sol passes through a maximum in 44±% acetone by volume.

In higher acetone concentrations a strong dehydration takes place.

A gradual increase of the per cent rise in relative viscosity in 44% acetone takes place at both sides of the point of maximal hydration of the gliadin sol.

Separation may be observed microscopically at both sides of this point in aqueous medium.

PROBLEMS PECULIAR TO THE PACIFIC NORTHWEST CEREAL CHEMIST

T. R. JAMES AND J. W. MONTZHEIMER

Spokane, Wash.

(Read at the Convention, May, 1930)

Every cereal chemist have heard the age-old alibi that all variations in flour are due to differences in the wheat. Now in describing some of the problems of the western cereal chemist we must again admit that the wheat is the cause of all our troubles.

Pacific Northwest wheat-producing areas are bound by Idaho, Washington and Oregon. The combined production for these three states annually runs 90,917,265 bushels. Another 6,500,000 bushels of Hard Red Spring and Hard Red Winter are shipped into these States from Montana for manufacture. We must consider this wheat too when figuring the large number and varieties of wheat that these mills must dispose of.

The largest problem which every chemist in this section must solve each year, the best way possible, is how to utilize to advantage the large number of wheat varieties which are grown by farmers in these States. It must be remembered that all of these varieties are more or less different and at times the price of one may be more advantageous to the miller than another. Gluten quality not only varies from one variety to another but the same variety shows wide differences according to the district where it has been grown.

In order that we may see just how vast this difference really is we may compare Montana and the other three States in which we are interested. Ninety-six per cent of all the wheat grown in Montana is of two varieties, namely, Hard Red Spring (Marquis) and Hard Red Winter (Turkey). In the State of Washington the acreage is given over to growing over twenty-five varieties; 30% is Hard White Baart and Bluestem, 25% is Turkey, and 55% is distributed more or less evenly between twenty-two other varieties. Oregon farmers grow about twenty-one different kinds; 26% being Turkey, 10% Gold Coin, a Soft White and 35% Club and Club Hybrids. This leaves 30% of their acreage to divide among eighteen other varieties. Idaho grows 18% Baart and Bluestem, 10% Dicklow, a Soft White, 15% Marquis and 26% Turkey, leaving about 30% of their acreage devoted to fifteen other varieties.

Each year new varieties are introduced and many times these show entirely different characteristics than the kind for which they have been substituted. The farmer has spent most of his time trying to find better yielders, while the requirements of the mills have not even been considered.

In order that you may get a better idea of how many varieties really are grown, let us check the acreage for the state of Washington over a four-year period.

We have 30% of the acreage devoted to growing Hard White of the following varieties: Baart, Bluestem, Hard Federation, Burbank, Defiance and Bunyip.

25% of the acreage is devoted to Soft White Wheats, the following wheats being grown: Gold Coin, Forty Fold, Soft Federation, Club, five different Club Hybrids and Jenkins Club. 5% of the acreage is devoted to Hard Red Spring (Marquis). 25% is devoted to Hard Red Winter, chief of which are Turkey and Ridit. 15% is devoted to Soft Red Winter, chief of which are Jones' Fife, Triplett, Red Russian, and Coppei. Other varieties not mentioned are only grown on less than one per cent of the total acreage.

Besides the above-mentioned varieties which each mill receives and must blend off, it must be remembered that almost every mill purchases its share of the wheat grown in Montana and manufactured here. These varieties must be binned and kept by themselves for various blends and bakers grades.

In addition to the problem of handling a large number of wheat varieties, the Pacific Northwest chemist has a large range of protein within each variety, which presents a considerable problem from the standpoint of milling a uniform flour.

Washington Baart received at Spokane this year has ranged from 9.0% to 14.5% protein, Washington Turkey from 8.0% to 14.0%, and Washington Marquis from 8.5% to 14.0%. (All protein figures are on 13.5% moisture basis.) Montana Marquis ranging from 11.5% to 18.0% protein has been received, and Montana Turkey from 11.05% to 15.0% protein.

Among varieties received in smaller quantities were Hard Federation from 10.5% to 14.0% protein and Club from 7.5% to 13.0% protein.

While writing principally on the basis of figures at Spokane, we have other figures which are not for small lots but for type samples, each representing a considerable quantity of wheat. These figures cover most of the wheat districts of Washington, Oregon and Idaho. This data shows Turkey varying from 7.6% to 14.5% protein, Western Red from 7.8% to 12.8%, Baart from 11.0% to 14.4%, Soft Federation from 7.1% to 11.4%, Forty Fold from 8.0% to 12.6%, Club from 7.9% to 11.5%.

Many of the Pacific Northwest mills do not have large elevators and very few are equipped with a reasonable number of bins for blending before storing in the large elevator bins. Therefore, most of the chemists in our section have a continuous puzzle to work on in the problems of binning wheat.

Naturally the milling of so many varieties is in itself a problem. The chemist must be careful in making his blends to give a combination that can be properly tempered, usually with a limited number of tempering bins. Also many of the smaller mills attempt to grind all kinds of flour using only one unit and even mills using more than one unit oftentimes are forced to grind flour on a unit unsuited for the purpose.

Aside from problems in milling, are those presented to the chemist, who must test all these varieties. While many wheats in this section are best suited to pastry flour even the low protein wheats show a large variation in the quality of their gluten. Pro-

tein alone means nothing in testing these wheats and the chemist must use his judgment and devise ways of testing the wheats to as to best segregate those of different gluten quality. The viscosimeter is used by some for this work and others have attempted to actually measure the stretching and breaking point of the gluten with an extensimeter. Really reliable methods are still lacking. The baking test on the pastry type of wheats proves more or less unsatisfactory.

In testing baker's grade flours in this section, we are confronted with wheats of widely variable fermentation periods. On one hand we have the white wheats with rather good quality gluten but low in fermentation tolerance, some of the shorter patents requiring only about three hours in the ordinary laboratory formula to reach their limit. Montana spring wheat flour, on the other hand, will stand up over five hours under identical conditions. Hard spring flour made from wheat grown in Washington as compared with Montana, shows a large difference in fermentation time, as also in the baking quality. Naturally blends of these various wheats give flour varying in fermentation time required somewhere between three and five hours. Any attempt to ferment all these flours exactly the same fermentation time, leads to conclusions which are at best difficult to interpret.

Since so many varieties are grown, it means that it will be found impossible to secure certain of them later in the season that may seem plentiful at first and which may have been used in some of the blends to such a degree as to affect the quality of the flour when other varieties are substituted. It may be suggested that the remedy for this situation is to use only varieties of wheat which are grown abundantly. However, it is usually these standard varieties which command a better price than their equivalent of the less well-known varieties, and the chemist cannot ignore economics in his work.

The situation has one cheerful aspect at least, as it seems to be improving. Fewer varieties are being grown each year, and since there is a tendency to pay a somewhat higher price for the more standard varieties, we believe that the improvement will continue.

BOOK REVIEW

The Microbiology of Starch and Sugars. By A. C. Thaysen and L. D. Galloway. 336 pages. Price $8.50. Oxford University Press, New York. 1930.

This book will prove attractive to the practical microbiologist and chemist who is interested in the identity of the microflora of cereals and other farinaceous materials, as well as the changes produced by these organisms. Scientists who are interested in the subject from a purely academic point of view will find the volume to be of considerable service not alone because of the discussion in the text but also because of the excellent bibliography of the literature. Commercial applications are not overlooked, however, and are discussed in the appropriate positions in a concise manner.

This volume is a companion to the book by Thaysen and Bunker entitled: "The Microbiology of Cellulose, Hemicelluloses, Pectins and Gums" which was published by the Oxford Press in 1927.

The book here reviewed is divided into five parts, which in turn are subdivided into a total of thirty-three chapters. In Part 1, the constitution and biochemical properties of starch, glycogen and inulin are outlined. Microflora responsible for the hydrolysis of these substances is discussed, as well as the hydrolysis of di-, tri,- and tetra-saccharides and certain glucosides.

In Part 2 is described the mechanism by which monoses are fermented to various end-products. This includes a discussion of aerobic and anaerobic dehydrogenation of hexoses. The production of butyric, lactic, propionic, gluconic and citric acids, of butyl alcohol and many other products is presented in this section. There is also consideration of the fermentation of pentoses.

Part 3 is devoted quite largely to the synthetic activities of microorganisms. The synthesis of starch and other polysaccharides is discussed, as well as the formation of mucus from carbohydrate substrates by various molds and bacteria.

Part 4 is devoted to the microbiology of cereals and cereal products, and thus should prove of special interest to the cereal chemist. The epiphytic flora of the growing grain is considered, with particular reference to the effect of climatic conditions upon this flora, and the contributions made to it by the microflora of the soil. A survey of the changes attributed to microflora in stored cereals containing varying percentages of moisture is presented in this section, together with a review of the literature which make reference to the properties of flour mill products manufactured from such cereals. The flora of ordinary bread dough and of the causative agents of bread diseases are also discussed in the same section.

Part 5 deals with the organisms encountered in the cane and beet sugar industries, particularly as these are related to the problems of the manufacture and storage of sugar.

It is difficult, of course, for the authors to completely cover the details of these numerous subjects within the confines of a book of this size. This difficulty is offset in part by the inclusion of a rather extensive bibliography, which enables the worker to use the book as a review of the literature, and as a point of departure for further study in his own particular fields of interest. Its use in this connection is facilitated by the inclusion of both subject and author indexes.

In addition to being well documented, the text is easy to read, due to a pleasant style of writing. Moreover the chemist without more than the usual fund of microbiological knowledge may read the book with pleasure and understanding since the taxonomic terminology is not distastefully prominent. It serves to emphasize, however, the fact that some microbiological training is desirable in the education of the food chemist.

—MILLARD F. GUNDERSON.

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